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Sampling and Modeling of Non-Point Sources at a Coal-Fired Utility

Research Corp. of New England, Wethersfield, Conn.

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16. ABSTRACT The report gives results of a measurement and modeling program for non-point sources (NPS) from two coal-fired utility plants, and the impact of NPS on receiving waters. The field measurement survey, performed at two utility plants in Pennsylvania, included measurement of overland runoff from NPS and river sampling upstream and downstream of each plant site. NPS sampled were storm water runoff and leachate from coal storage piles and runoff from impervious areas such as parking lots and roofs which were covered with dust fallout from coal and ash handling operations. A mathematical model was developed to simulate both the quantity and quality of industrial NPS pollution and its impact on receiving waters. Field data indicated that NPS pollution from utilities had little impact on the two rivers, compared to the impact from sources upstream of each site. Modeled results compared to field measurements within a factor of 4 for both the quantity and quality of storm water runoff and its impact on the quality of the receiving waters. Field survey results indicate that, for a cost-effective program, sampling must be supplemented with modeling (the modeling results indicate that the developed model can be used with a minimum of field data to successfully simulate industrial NPS pollution and its impact on receiving waters for the utility industry).

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SAMPLING AND MODELING OF NON-POINT SOURCES AT A COAL-FIRED UTILITY

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1.0 INTRODUCTION

Since the enactment of PL 92-500 (Federal Water Pollution Control Act Amendments of 1972), the U. S. Environmental Protection Agency has directed its water pollution control program primarily at point source emissions which include wastewater discharges through pipes to receiving bodies of water. Most industries and many municipalities will meet the 1977 standards. However, there are numerous areas in the United States where water quality has not significantly improved even though point sources have been controlled. In such areas non-point source water pollution often has a major influence on water quality. This is documented by the National Commission on Water Quality which reported that "non-point pollutant sources are significant to the Commission's study because they may in some instances overwhelm and negate the reductions achieved through point source effluent limitations".(1) Based on these findings, the Commission recommended to Congress that "control or treatment measures shall be applied to agricultural and non-point discharges when these measures are cost effective and will significantly help in achieving water quality standards".(2)

Non-point sources are not specifically defined in PL 92-500. For this program the following definition applies:

> *the accumulated pollutants in a receiving body of water from runoff due to snow melt and rain, seepage and percolation, and chemical spills and leaks, contributing to the degradation of the quality of surface waters and groundwaters.*

As defined, non-point sources have some or all of the following characteristics:

- Diffuse in nature
- Intermittent
- Site specific
- Not easily monitored at their exact source
- Related to uncontrollable meteorological events (precipitation, snow melt, drought)
- Not usually repetitive in nature from event to event

The primary transport mechanism for non-point sources is water runoff from meteorological events. Figure 1-1(3) is a simple representation of the runoff cycle. This figure shows three basic modes of runoff transport: overland flow, interflow, and groundwater flow. The quickest means of transport is direct overland flow, commonly called surface runoff. Surface runoff will usually contain the highest quantity of contaminants and, except during snow melt conditions, does not usually flow for a long duration after a storm event.

The second means of transport is infiltration (seepage) into the soil and then transport by interflow (also called interstitial flow) through the ground to either a receiving body of water or, depending on terrain, percolation back to the surface to become surface runoff. Interflow contaminants are often filtered by the soil. The interflow route is between the surface and the water table and, depending on the soil and geological conditions, can be rapid.

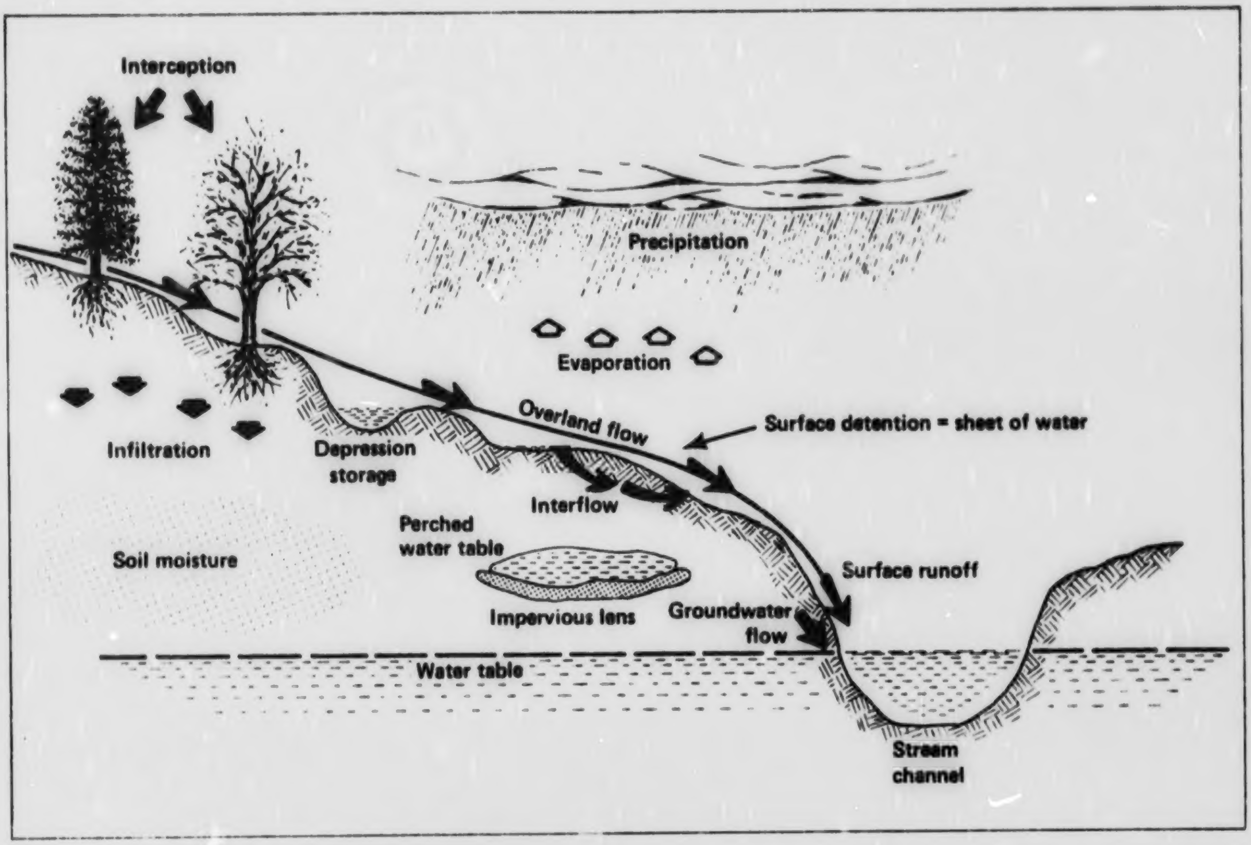

Figure 1-1: Simple Representation of the Runoff Cycle

The third transport route, by far the slowest, is infiltration (seepage) to the water table followed by groundwater flow to a receiving body of water. While the soil may filter contaminants, any pollutants which enter the groundwaters could persist for years.

The scope of this program is directed toward surface runoff for the following reasons:

1. Surface runoff is the quickest means for transporting pollutants to receiving waters and usually contains the highest quantities of contaminants and flow.
2. Depending on terrain, measurement of surface runoff will also include quantities of interflow (interstitial flow).
3. While sampling non-point sources is difficult, surface runoff presents the easiest means for tracking and measuring these sources.

In January, 1976, an evaluation of the scope of the waterborne fugitive emissions (non-point sources) problem was initiated. The objectives of the initial program were:

- To develop a matrix relating sources of industrial non-point pollution to categories of pollutants.
- To evaluate present sampling techniques used in non-point programs based on practicality and efficiency, and to propose a Level 1 (overall identification) sampling program for industrial activities.
- To evaluate existing mathematical models for predicting non-point source pollution based on their suitability, adaptability, complexity, cost, and availability for quantifying runoff and predicting its associated impact on receiving waters.

This work was completed in June 1976 and is summarized in Section 3.1 of this report. Based on the results of this initial program, a follow-on program was initiated with the following objectives:

- Design a test program for sampling runoff and receiving waters for an industrial site.
- Using the test plan, quantify and qualify runoff from two coal burning utilities and measure the effect, if any, on the receiving body.
- Choose one of the models evaluated in the previous work and adapt it for use in the coal burning utility industry.
- Calibrate and verify the model using the field data.

Section 3.2 describes the field survey and results. The model description, development, and results are detailed in Section 3.3. Conclusions and recommendations for further work are summarized in Section 2.0.

This report is part of a two-volume set. The other volume entitled "Technical Manual for the Measurement and Modeling of Non-Point Sources at an Industrial Site on a River" provides a general guide for performing a program such as the one described in this volume.

2.0 CONCLUSIONS AND RECOMMENDATIONS

2.1 Conclusions

This program began with a background review of non-point source water pollution from industries. Included in the review was an evaluation of measurement methodology and prediction methodology which could be utilized in an assessment of non-point sources from an industrial site.

Based on this initial review, the following conclusions were reached:

1. Only urban and agricultural non-point sources have been quantified to any extent, while little has been done toward isolating and quantifying non-point sources from industrial activities.
2. Non-point sources most probable to industrial sites are:
    a) Runoff from material storage piles
    b) Runoff from accumulated materials due to fallout from fugitive and point source air emissions.
3. Non-point sampling programs have generally included only measurements of the quality of the receiving waters. Little has been done with sampling actual runoff except in urban storm sewers and agricultural ditches.
4. With the exception of agricultural and mining activities, mathematical models have not been developed to simulate stormwater runoff and receiving water impact specific to industries.
5. Five of ten models evaluated are capable of dynamically simulating the quantity and quality of both stormwater runoff and its impact on the receiving waters.
6. All of the five models referred to in item 5 can be adapted for industrial non-point sources; of these, however, three are proprietary, and only one is completely in the public domain. The other model is part proprietary and part in the public domain.

Using these conclusions, a field survey for sampling stormwater runoff and receiving waters at industrial sites was designed and performed. The sites chosen were located at two coal-fired utility plants in Pennsylvania. One plant was near the headwaters of the Allegheny River in Warren, Pennsylvania. The second plant was on the Delaware River in Portland, Pennsylvania, near the Pocono Mountains. In addition, one of the models evaluated in the background review was adapted for use in the coal burning utility industry.

The following conclusions resulted from the field survey and mathematical model development in this program:

1. The pollutant concentrations in the river at both sites were highly variable, often by an order of magnitude. These variations were independent of river flow and weather conditions.

2. The mass loading of pollutants in the Delaware River increased substantially during and after the sampled storm event. This was due primarily to an increased flow attributable to upstream conditions and storm intensity. The mass loading of pollutants in the Allegheny River remained essentially unchanged for both sampled storm events since river flow was controlled by a dam approximately six miles upstream and neither storm event was substantial. Therefore, the pollutant concentrations in each river at both upstream and downstream sampling stations were not necessarily higher during storm conditions.

3. The data from these two sites generally show no statistical difference in mean concentrations of upstream versus downstream pollutant levels in either dry or wet conditions.

4. The data show no statistical difference in sample variances which are not consistently predictable with respect to pollutant, site, and sampling period.

5. The main contributors to the change in S^2 of the calculated variance were site location and the storm event. The site location was the major contributor at Warren while the rain event was the major contributor at Portland. The sample variances were generally consistent for each pollutant at the Warren and Portland Sites. The only exceptions were total suspended solids and iron.

6. The storm data from Warren shows a "first flush" effect from the initial runoff of the access road which contained fugitive fallout from the coal pile and coal trucks.

7. The pollutant concentrations of the leachates from the coal pile at Warren were orders of magnitude higher than the storm runoff pollutant concentrations. For a short duration moderate intensity storm and a moderate duration low intensity storm (the two events sampled at Warren), the leachate mass loading was greater than the storm mass loading because the leachate drained for several days. Thus, for the two storms sampled at Warren, the pollutant loads on the river from the power plant were less during rain than during the dry weather period following the rain with the exception of total suspended solids.

8. The sample plugs worked effectively except for one problem; dry solids filtered through the screen prior to runoff and leached into the sample, creating higher measured pollutant concentrations.

9. The field survey results from the two utility sites indicate that more field survey work must be performed at industrial sites before control measures can be taken.

10. The SSWMM - RECEIV II model is capable of predicting the quantity and quality of stormwater runoff and its impact on receiving waters for specific industries with model limitations. These limitations include the lack of capability to simulate storm erosion of infinite sources, i.e., material storage piles, and to simulate stormwater percolation through material storage piles.

11. Application of the model to the utility industry has demonstrated that for the most part, where adequate field data were available, the model results compared favorably to field measurements.

12. At Warren, calibrated model results for stormwater runoff flow and pollutant concentrations (total suspended solids, total iron, manganese, and aluminum) compared within a factor of four to field measurements, and river pollutant concentrations for all six pollutants compared within a factor of three. EPA has indicated that an agreement within a factor of four to five should be considered indicative of a good predictive method. A model-field measurement comparative factor of four was maintained for a second storm at Warren indicating that the calibrated model could predict the effects of different storm conditions with the same degree of accuracy established in model calibration.

13. Due to a lack of runoff flow data at the Portland site, it was not possible to ascertain the comparative validity of the model at more than one site.

2.2 Recommendations

Based on the conclusions of this program, the following recommendations are made for future work:

1. Develop the SSWMM - RECEIV II model capability to simulate the erosion of material storage piles, and to simulate the percolation of stormwater runoff through materials storage piles.

2. Conduct additional field surveys to provide data to compare to model predictions, thus enhancing model credibility. Specifically, more field data are required on:

   a) Stormwater runoff flow and pollutant concentrations from industrial sites.

   b) Dust and dirt accumulation rates and the amount of pollutants in the dust and dirt.

   c) Flow and pollutant concentrations after the storm for the leachate from material storage piles.

   d) Receiving water pollutant concentrations. To acquire definitive representative receiving water pollutant concentrations (background and storm-induced), it will be necessary to increase the number of sampling stations in the receiving water upstream and downstream from the stormwater discharges. At least two, and preferably three, such stations should be established at both the upstream and downstream sites. With a single upstream station, the risk is greater of measuring an anomaly in the river characteristics. The additional upstream stations would be located either in an "across the flow" pattern or longitudinally with flow depending on river mixing characteristics to insure that the sampling locations and data are representative of the river. The additional downstream stations would be located longitudinally in the river to allow for better definition of the impact of stormwater runoff on the river (i.e., dilution and reaction of non-point pollutants in the river).

3. Once model credibility has been enhanced, apply the model to a site on an estuary or lake and compare the results with those of a field sampling program.

4. Upon completion of items 1, 2, and 3 prepare a User's Manual for SSWMM - RECEIV II to enhance the model's use.

3.0 PROGRAM DESCRIPTION

This project consisted of three major tasks. The background review, the initial task, included an evaluation of potential non-point sources from industry, a review of sampling techniques to quantify non-point sources, and an evaluation of existing mathematical models for predicting the impact of non-point sources from industrial sites. The second task involved a field survey to quantify non-point sources at two coal-fired utility plants in Pennsylvania. The final task was the adaptation of a mathematical model to predict stormwater runoff from a coal-fired utility.

3.1 Background Review of Non-Point Source Water Pollution

A non-point source was defined in Section 1.0 and the primary means of transport (runoff, interflow, and groundwater flow) were discussed. Figure 3-1(4) illustrates the most common non-point sources and Table 3-1 demonstrates that most of these sources are rated as Areas of Concern by the states in their 305(b) reports (PL 92-500) to EPA.(5) The following summarizes some of these common non-point sources:

Urban Sources - Rainfall dislodges pollutants from street surfaces, rooftops, lawns and other urban environments, causing contaminant particles to become suspended and dissolved in the runoff. Pollution concentration is therefore greatest at the beginning of a rainfall event. This phenomenon is commonly called "first flush".

The most common pollutants in urban runoff are dust, pathogens, fertilizers, pesticides, battery acid, rubber, grease, oil, animal and

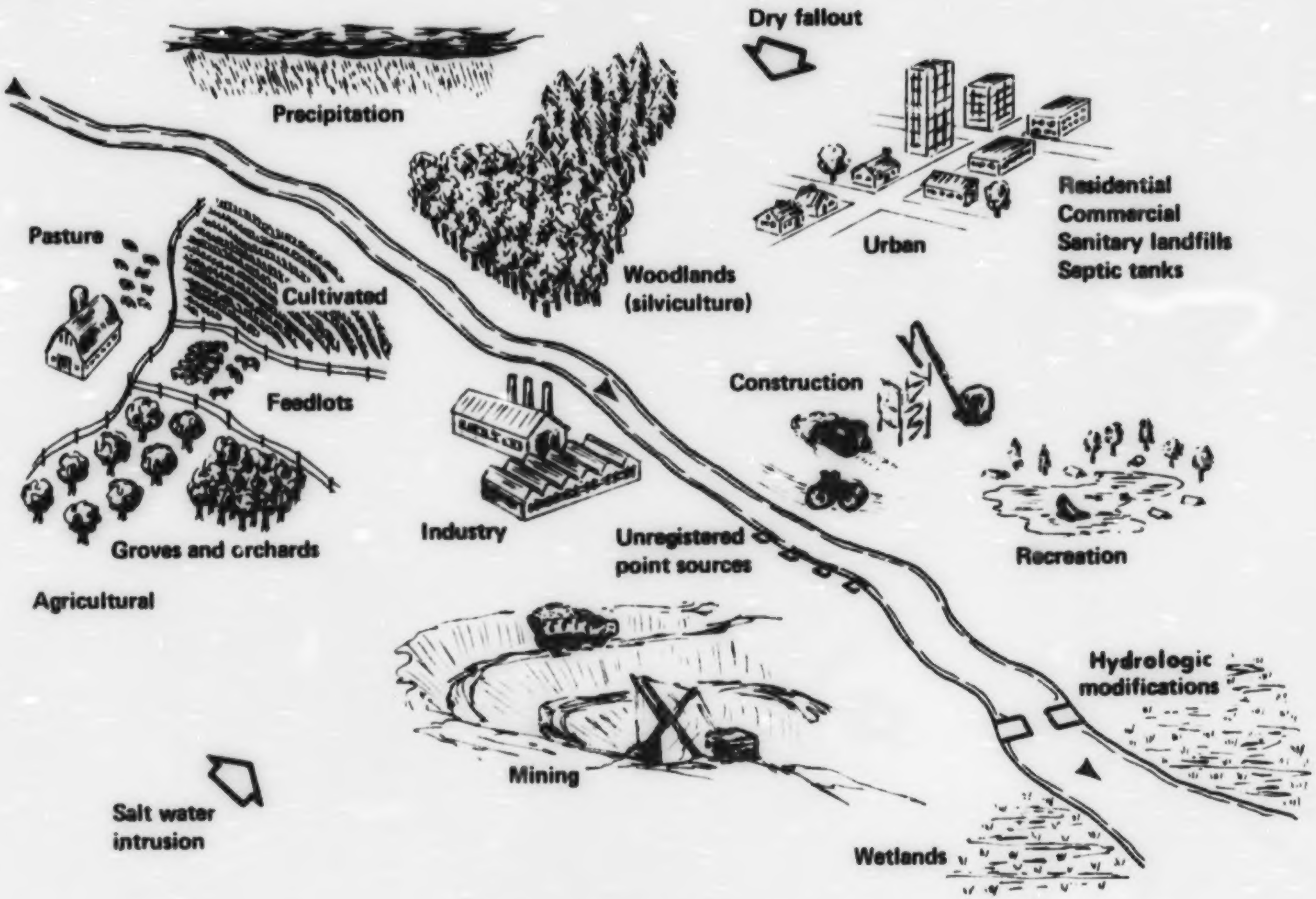

Figure 3-1: Non-point sources

TABLE 3-1

NON-POINT SOURCE PROBLEMS LISTED IN STATE 305(b) REPORTS

	Non-Point Source Problems							
	Agricultural	Sivicultural	Mining	Construction	Hydrologic Modification	Urban	Salt Water Intrusion	Proposed Energy Development
Alabama	X	X	X			X		
Alaska *								
American Samoa								
Arizona†								
Arkansas	X	X	X			X		
California	X	X	X	X	X	X	X	
Colorado	X	X	X			X		X
Connecticut	X			X		X		
Delaware	X					X		
District of Columbia				X		X		
Florida	X	X	X			X	X	
Georgia	X					X		
Territory of Guam	X			X		X		
Hawaii	X					X		
Idaho	X	X	X	X		X		
Illinois	X		X			X		
Indiana	X		X	X	X	X		
Iowa	X					X		
Kansas	X		X	X		X		
Kentucky	X	X	X					
Louisiana	X	X	X			X	X	
Maine	X	X	X	X		X		
Maryland	X	X	X			X		
Massachusetts*								
Michigan†								
Minnesota	X			X	X	X		
Mississippi *								
Missouri *								
Montana	X	X	X					
Nebraska	X			X		X		
Nevada	X	X	X	X		X		
New Hampshire	X	X	X	X	X	X		
New Jersey	X			X		X		
New Mexico	X				X			X
New York	X			X	X	X		
North Carolina	X			X				
North Dakota†								
Ohio	X	X	X	X		X		
Oklahoma	X		X			X		
Oregon†								
Pennsylvania	X		X			X		
Commonwealth of Puerto Rico	X					X		
Rhode Island	X		X	X		X		
South Carolina	X					X		
South Dakota	X					X		
Tennessee	X		X	X	X	X		
Texas	X	X	X		X	X	X	
Trust Territories				X				
Utah	X	X	X	X		X		
Vermont	X	X	X	X				
Virginia	X	X	X	X		X		
Virgin Islands				X				
Washington	X	X	X		X	X		
West Virginia	X	X	X	X		X		
Wisconsin	X			X		X		
Wyoming	X	X				X		X
Totals	44	21	27	25	9	40	4	3

*State report was not received in time for inclusion.
†Not discussed by category

bird droppings, heavy metals, salts, sand, gravel, coal, leaves, paper products, plastics, and glassware.

Agriculture - Runoff from cultivated crop fields, forage crop fields, orchards, vineyards, rangeland, pasture land, confined animal feedlots, and aquaculture project areas producing algae, shellfish, and finfish are sources of non-point pollution. When forests or grass lands are cultivated, erosion is increased.

Crop fertilization provides nutrients, principally phosphates and nitrates, which are transported into lakes and streams, thereby accelerating eutrophication. Irrigation can leach salts out of the soil, and pesticides used for control can be transported to receiving waters. Runoff from rangelands, pasture lands, and feedlots (for beef, dairy, pork, and poultry) carries significant amounts of suspended solids, nutrients, coliform bacteria, organic materials, and salts.

Silviculture - This activity which includes the harvesting of trees, log transport, and forest regeneration has several potential non-point sources. Removing the forest canopy along shallow stream banks and lakes causes water temperature to rise and thus affects the biota. The harvesting of timber increases surface runoff, which transports suspended and dissolved solids and organic materials to surface waters. Log transporting activities cause increases in runoff containing sediment. Fertilization and pest control cause nutrients and pesticides to be transported to streams.

Recreation Areas and Wetlands - These areas comprise non-point sources which are a combination of those listed under agricultural and silvicultural activities. Sediment (suspended and dissolved solids), organic materials and nutrients (compounds of nitrogen and phosphorous) are the primary contaminants.

Hydrologic Modifications - These non-point sources are related to dam construction, dredging, and other channel activities. The major contaminant is usually sediment.

Salt Water Intrusion - Salt or saline water seeps into fresh water aquifers (groundwater) thus contaminating fresh water supplies. Intrusion results from encroachment of seawater into coastal areas, from man-made saline wastes such as road salts or deepwell injection, and from return flows to streams from irrigated lands.

The objectives of this program are concerned with non-point sources from industry. Subsections 3.1.1 through 3.1.3 describe in detail potential non-point sources for industry, measurement methodology applied to industrial non-point sources, and the mathematical modeling of such sources.

3.1.1 Evaluation of Industrial Non-Point Sources

Little data is available for quantifying and qualifying non-point sources from industrial sites. Twelve industrial categories listed in Table 3-2 have Effluent Guidelines and Standards (proposed or final) which mention, define, and/or limit non-point sources of pollution in various sub-categories. Each of the industries was assessed for types of non-point sources and categories of pollutants. Generally, the sources with the highest potential for non-point pollution in these

TABLE 3-2

INDUSTRIES WHOSE PROPOSED OR FINAL EFFLUENT GUIDELINES REFERENCE NON-POINT SOURCES

Cement Manufacturing

Inorganic Chemicals

Fertilizer Manufacturing

Petroleum Refining

Iron and Steel Manufacturing

Nonferrous Metals

Phosphate Manufacturing

Steam Electric Power Generating

Timber Products

Coal Mining

Mineral Mining

Ore Mining and Dressing

industries are runoff from material storage piles and runoff from accumulated materials due to fallout from fugitive and point source air emissions. The categories of pollutants associated with these sources are:

- Sediment (suspended and dissolved solids)
- Organic Materials (materials which cause an oxygen demand either biochemical or chemical)
- Metals (lead, zinc, mercury, iron, copper, cadmium, etc.)
- Nutrients (compounds of nitrogen and phosphorous)
- Sulfates

The primary effluent limitations for industrial non-point sources are for sediment (suspended and dissolved solids). All industries listed in Table 3-2 will have a total suspended solids (TSS) limitation. The limitations which are already promulgated, such as those for the Steam Electric Power Generating Industry have a TSS range of 20-50 mg/l maximum daily concentration and 10-25 mg/l average monthly concentration.

While only specified industries must comply with emission regulations concerning non-point sources, all industries must meet water quality standards if they discharge to a receiving water body. If water quality standards are being violated, industry may have to quantify its non-point sources and determine the impact on the receiving water body to determine if these sources need to be controlled.

3.1.2 Measurement Methodology

One of the initial objectives of the program was to evaluate the practicality and efficiency of present sampling techniques used in non-point programs and to propose an overall identification sampling program for industrial activities.

A measurement program designed to quantify non-point source pollution from industrial activities should include runoff sampling (generally of contaminated stormwater) and receiving water sampling. Runoff sampling is used as a means of isolating the particular sources, while receiving water sampling is used to determine the impact of the runoff on the quality of the receiving water. This impact on water quality is important since non-point pollution is site specific and there are locations where an industry may be meeting the emission limitation for non-point sources and yet may have to improve control because of water quality limitations. The information from such a survey can ultimately be used to determine whether the facility should be controlled, and, if it can be controlled, how much control is necessary.

Since runoff is site specific, background information such as topography, geology, hydrology, climatology, and area land use must be obtained in order to design the field survey. In addition, industry operating procedures should be obtained in an industrial program.

The evaluation of sampling techniques to be used in a field survey included a literature review. In general, industrial runoff has not been separated from urban runoff and very little data exists for industrial sources such as material storage piles. There is a great deal of information on sampling receiving water bodies and runoff with specific reference to urban runoff (storm sewers) and combined sewer overflows.(6)(7)(8) The next three subsections describe the types of samples required and some means available for sampling, as well as an approach to sampling both receiving waters and runoff.

To provide a representative evaluation of the characteristics of runoff and its effect on the receiving body, a number of storm events should be studied. Storms of different intensities and durations, with different intervening intervals of dry weather should be sampled. Generally, storms of high intensity are of short duration (e.g., thunderstorms) and are more important than storms of low intensity and long duration because the greater the intensity of the storm, the greater the quantity of materials that will be scoured from the land surface.

3.1.2.1 Selection of Sample Type and Sampling Method

There are two basic types of samples which should be used in a field program for quantification of non-point sources: discrete and composite. A composite sample is a series of discrete (individual samples). Discrete samples are best used for definition of a single storm event while composite samples are used for long-term or average storm conditions. These samples can be collected either manually or by automatic samplers. Table 3-3 compares discrete and composite samples as they relate to a runoff field survey and also compares manual versus automatic sampling.

There are several drawbacks to manual sampling. First, a manual sampling program requires the use of trained personnel. This was verified by Shelley(9) who reported that a significant difference in sample analyses resulted between samples collected by trained and untrained personnel.

TABLE 3-3

COMPARISON OF TYPES OF SAMPLES AND MEANS OF SAMPLING

Comparison of Discrete and Composite Samples	
Discrete	Composite
1. Produces a large number of samples.	1. Produces a small number of samples.
2. Allows comparison of runoff qualities over a period of time.	2. Gives an integrated or total picture of runoff qualities instead of isolated qualities at different times.
3. Best used in definition of a single storm event.	3. Best used for long term, multiple storm definition or average storm definition.
Comparison of Manual and Automatic Sampling	
Manual	Automatic
1. Manpower requirement is quite large.	1. Manpower requirement is minimal; only maintenance and removal of samples require manpower.
2. Sample collection equipment expenditures are not excessive. Simple submersible pumps and/or weighted water samples suffice.	2. Sample collection equipment becomes a capital expenditure because it is automated and must be sheltered from weather and vandalism and often must be specially designed.
3. Field measurements can be made by individual or combined meters.	3. Field measurements can be made by meters used in conjunction with the automatic collection system, or the meters may be designed into the system.
4. The beginning of the storm event can be missed if mobilization of manpower is not immediate.	4. Since automatic collectors can be activated by the beginning of precipitation or an increase in flow of water level, the beginning influence of the storm will not be missed.
5. Samples will be unrepresentative if untrained collectors are used.	5. Samples will be lost or nonrepresentative only if equipment malfunctions or power source is interrupted or depleted.
6. If samples need to be collected at close time intervals, extensive manpower may be required at each station or the intervals may be missed altogether.	6. Automatic samplers make collection easier at close time intervals.

Second, the "first flush" effect of storms cannot be effectively sampled because of the problems associated with mobilization of manpower. Finally, manual sampling of a storm event may be physically dangerous to personnel if the increase in water level and/or flow is greater than anticipated.

3.1.2.2 Sampling Receiving Waters

Sampling of receiving waters, i.e., streams, rivers, lakes, estuaries, can be performed either manually or automatically. The economics and the required accuracy will dictate the sampling approach.

The concentration of a particular pollutant in the receiving water depends on the natural background quality of the receiving water, the upstream flow conditions, and the characteristics of both the test site itself and the drainage areas adjoining the test site (e.g., size of areas, potential materials which can be transported to the receiving water by runoff). Thus, sampling should be conducted in both dry and wet weather conditions both upstream and downstream of the source on a river. The dry weather water quality data will provide a basis for comparison when reviewing the wet weather information. At least one upstream station should be established because upstream inputs may change as a result of wet weather or as a result of changes in plant operating procedures of upstream industries. The number and location of downstream stations should be determined from a review of the available maps and plant operating information. Any significant intercepting water bodies should be noted and sampled for their contributions to the water quality of the main stream. Each of these sampling locations should be selected based on the drainage patterns of the test area. The development of drainage basins and selection of the sampling locations is detailed in the second volume of this program entitled "Technical Manual for the Measurement and Modeling of Non-Point Sources at an Industrial Site on a River".

If the receiving water is an estuary or lake, the sampling stations should be located using one of the following procedures: review of historical current data; a preliminary survey using parameters such as turbidity, conductivity, dissolved oxygen and temperature; or a mixing study using dye as a tracer.

If the receiving body is relatively wide and deep and not well mixed, a number of sampling stations should be located across the water body and at several depths. Curves and abutments in the receiving body should be avoided when sampling because they alter flow patterns.

3.1.2.3 Sampling Runoff

A literature review provided a significant amount of information relative to the measurement of urban runoff, predominantly in storm sewers. As disclosed in the search, the only work specifically performed on non-point sources from industrial activities involved the use of irrigation ditches to sample agricultural runoff. At the time of this review, there were no well-documented sampling procedures for overland runoff from industrial sources such as material storage pile drainage or runoff of materials deposited on the ground from fallout of fugitive and point source air emissions.

Leachate tests can be helpful in isolating the contaminants in the runoff from storage piles, since such tests would relate the pile aging process to runoff pollutant concentrations. These data, however, cannot be correlated directly with actual rainfall data, the quantity of runoff, and the behavior of the transport of runoff to the receiving water. While leachate tests may be applicable to material storage pile investigations, they are not applicable in estimating the accumulated effects of the materials on land, such as the area affected by an industrial facility.

A proposed method for measuring the quality of overland storm water runoff involves the collection of samples using a plug collector shown in Figure 3-2.(10) These plugs are driven into the ground at selected locations where runoff will occur, such as at the base of material storage piles and in natural gullies and channels. During a storm, the plugs are changed at regular intervals depending on the intensity of the storm. The volume of samples collected in several plugs in one area is composited and analyzed.

To obtain mass loadings of overland runoff, a gross estimate of stormwater runoff flow must be made. The test area is divided into drainage basins, based either on topographic plots or visual observations. The flow is estimated based on the total rainfall for the storm duration, the area of each basin over which runoff flows, and the soil permeability in the drainage basin.

3.1.3 Prediction Methodology

A field survey which includes both runoff and receiving water sampling is costly. Since runoff is site specific and non-repetitive, it is conceivable that the survey would have to be carried out during several storms at several sites to establish meaningful data for any particular

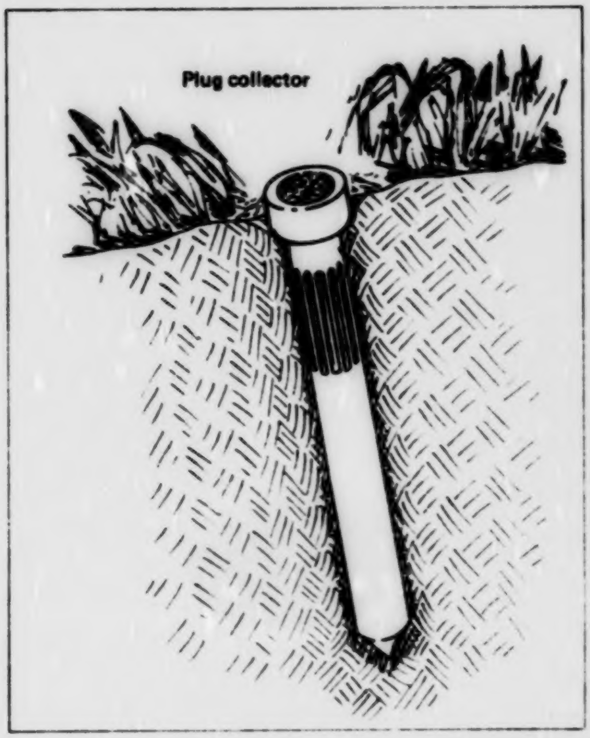

Figure 3-2: Plug Collector

industry. Since this is impractical from cost and time standpoints, the use of mathematical models for the prediction of non-point source pollution could well be more efficient. Mathematical models properly applied provide a cost-effective means of quantifying impacts on water quality resulting from stormwater runoff. They are also effective in evaluating alternatives for the control of non-point sources.

A literature review produced information on many mathematical models developed in recent years to simulate the quantity and quality of stormwater runoff and the impact of such runoff on the quality of natural water bodies. Each model, however, was developed to satisfy a different need ranging from the design of municipal storm sewer systems to the assessment of land use as it influences flooding and water quality. A model developed specifically for industrial runoff (except mining and agriculture) does not exist, although some models can be adapted to such use.

Most of the models were developed for land areas typical of either urban or agricultural environments. Therefore, the models must be adapted to the land use of the particular industry of interest. All models still require some field data for adaptation to a particular site.

There are many criteria that can be used when selecting a model. In general, the simplest model which satisfies the project needs should be selected for use since such a model is normally the most economic choice. Figure 3-3(11) illustrates one aspect which contributes to model complexity--the choice of parameters to be modeled. For instance, it is relatively more difficult to model toxicity relationships than to model dissolved oxygen levels.

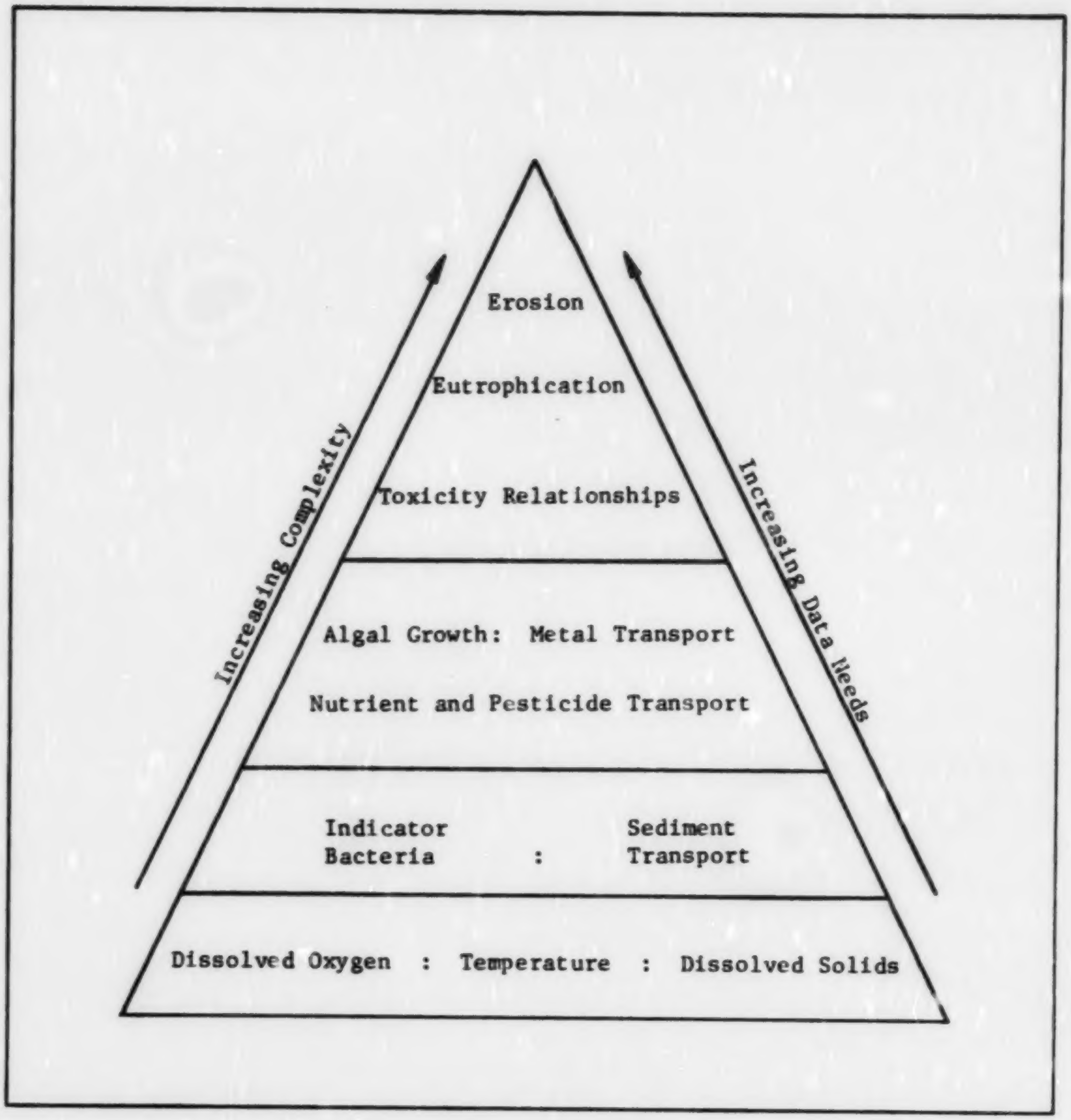
Erosion
Eutrophication
Toxicity Relationships
Algal Growth: Metal Transport
Nutrient and Pesticide Transport
Indicator Bacteria : Sediment Transport
Dissolved Oxygen : Temperature : Dissolved Solids
Increasing Complexity
Increasing Data Needs

Figure 3-3: Relative Difficulty of Applied Modeling

To select the simplest, most suitable model it is necessary to:

1. Define the objectives of the study.
2. Identify available models which appear to meet the study objectives.
3. Evaluate each model based on its ability to satisfy the study objectives within the technical and economic constraints applied.
4. Select for use the model most suitable for the project needs.

It is more important to fit the model to the problem rather than to fit the problem to the model.

Once a model has been selected, it must be adapted to the specific site or area being studied. A model is adapted through the processes of calibration and verification. Calibration is achieved by adjusting the model to reflect site specific field data. After the model has been calibrated, it should be tested against a second set of field data. If the second set of field data and the modeled results compare favorably, the model may be considered to be verified and ready for application. EPA has indicated that an agreement within a factor of four to five should be considered indicative of a favorable predictive method.

For a model to be adaptable to industrial applications, it must be capable of predicting the quantity and quality of stormwater runoff, the transport of such runoff to a receiving body of water, and the impact of such runoff on the quantity and quality of the receiving water. Pollutants of primary importance for model simulation include sediment (suspended and dissolved solids), nutrients (compounds of nitrogen and phosphorous), pesticides, acidity/alkalinity, pH, organic material (biochemical oxygen demand, chemical oxygen demand, dissolved oxygen), and heat (temperature). In addition, since storm events are dynamic, a model must also be capable of simulating functions in a dynamic, i.e., time dependent fashion.

To predict the quantity and quality of stormwater runoff a model must be capable of simulating the effects of such items as the intensity and the duration of the storm event, infiltration and drainage characteristics, the accumulation of pollutants between storms, and the washoff of such pollutants during storms. For continuous simulation of multiple storms, a model must be capable of simulating dry weather flows as well as storm flows.

To predict the transport of stormwater runoff for industrial land use, a model must be capable of simulating overland flow and routing in man-made systems (channels, sewers, etc.).

To describe the impact of the stormwater runoff on a receiving body of water, a model must be capable of simulating the quantity and quality responses of the receiving water to the runoff. Again, for continuous simulation of multiple storms, a model must be capable of simulating dry weather flows as well as storm flows. For increased flexibility, a model should be capable of simulating various types of receiving waters including rivers, lakes, and estuaries.

Based on these model requirements, the models listed in Table 3-4 were evaluated for suitability, adaptability, complexity, cost, and availability using the following criteria:

- Wastewater (Runoff) - quantity, quality, dry weather flows, storm runoff;
- Receiving Water - quantity, quality, river, lake, estuary;

TABLE 3-4

MODELS SELECTED FOR EVALUATION

EPA Stormwater Management Model - Release II (SWMM)

Water Resource Engineers Stormwater Management Model

Short Stormwater Management Model - RECEIV II (SSWMM - RECEIV II)

Hydrocomp Simulation Program (HSP)

Dorsch Consult Hydrograph Volume Method

Corps of Engineers Storage, Treatment, Overflow, and Runoff Model (STORM)

Battelle Wastewater Management Model (BWMM)

Metcalf and Eddy Simplified Stormwater Management Model

EPA - Hydrocomp Agricultural Runoff Management Model (ARM)

Pyritic Systems: A Mathematical Model

- Quality Parameters - temperature, suspended solids, total dissolved solids, biochemical oxygen demand (BOD_5), chemical oxygen demand (COD), dissolved oxygen, nitrogen, phosphorous, pH, oil and grease, pesticides;
- Simulation of Single Storm
- Simulation of Multiple Storms
- Computer Program Availability - Public or proprietary;
- Complexity - high, moderate, low;
- Costs - high, moderate, low.

The results of the model evaluation are summarized in Table 3-5.

The EPA Stormwater Management Model (SWMM), Water Resource Engineers Stormwater Management Model, Short Stormwater Management Model - RECEIV II (SSWMM-RECEIV II), Hydrocomp Simulation Program (HSP), and Dorsch Consult Hydrograph Volume Method are capable of dynamically simulating the quantity and quality of stormwater runoff and its impact on the quantity and quality of receiving waters. These models can best be described as runoff and receiving water models. The quality simulation portion of each of these models must be modified for industrial application. The quality relationships are based on land utilization with all types of industry lumped into one land use category - industrial. No attempt is made to specify the particular type of industry. To meet the program objectives, then, it is necessary to develop specific quality relationships, pollutant accumulation, and washoff characteristics on an industry-by-industry basis for each of the models in this group.

The Corps of Engineers Storage, Treatment, Overflow, and Runoff Model (STORM), Battelle Wastewater Management Model (BWMM), and Metcalf

TABLE 3-5

A COMPARISON OF MODEL CAPABILITIES, APPLICATION, COMPLEXITY, COST, AND AVAILABILITY

Model Identification		Model Capabilities																						Potential Model Application								
		Waste-Water				Receiving Water					Quality Parameters																					
Name	Date Released	Quantity	Quality	Dry Weather Flows	Storm Runoff	Quantity	Quality	River	Lake	Estuary	Temperature	Suspended Solids	Total Dissolved solids	BOD5	COD	Dissolved Oxygen	Nitrogen	Phosphorous	pH	Oil and Grease	Pesticides	Simulation of Single Storm	Simulation of Multiple Storm	Agriculture	Mining	Construction	Energy	Other Industries*	Program Modification Required	Relative Model Complexity	Relative Model Cost	Computer Program Available
EPA SWMM Release II	1974	X	X	X	X	X	X	X	X	X		X		X	W	X	W	W		W		X	X	X	X	X	X	X	X	H	H	X
WRE Stormwater Management Model	1973 +	X	X	X	X	X	X	X	X	X		X		X			X	X		X*		X		X	X	X	X	X	X	H	H	P*
Short SWMM/ RECEIV II	1976/1974	X	X	X	X	X	X	X	X	X		X		X		X	X	X				X	X	X	X	X	X	X	X	M	M	P/X
Hydrocomp Simulation Program	1974	X	X	X	X	X	X	X	X		X		X	X		X	X	X	X				X	X	X	X	X	X	X	H	H	P
Dorsch Consult	1975	X	X	X	X	X	X	X	X	X				X	D		D	D				X	X	X	X	X	X	X	X	H	H	P
Corps. of Engineers Storm	1975	X	X		X	D	D	D	D	D		W		W			W	W				X	X	X	X	X	X	X	X	M	M	X
Battelle Waste - Water Management Model	1976	X	X	X	X							W		W	W		W	W				X		X	X	X	X	X	X	M	M	X
Metcalf&Eddy Simplified Stormwater Management Model	1976	X	X	X	X							W		W			W	W					X	X	X	X	X	X	X	L	L	June 1976
EPA-Hydrocomp Agricultural Runoff Management Model	1976	X	X	X	X							W					W	W			W	X	X	X						M	M	X
Pyritic Systems: A Mathematical Model	1972	X	X	X	X						H_2SO_4 - Only												X		X				X	M	M	X

*Cement, feedlots; inorganic chemicals; fertilizer manufacturing; petroleum refining; iron and steel; non-ferrous metals; phosphate manufacturing timber

- Key -

X = Yes
W = Wastewater only
D = Currently being developed
P = Proprietary

H = Complex/costly
M = Moderately complex/moderately costly
L = Simple/low cost

and Eddy Simplified Stormwater Management Model are capable of dynamically simulating the quantity and quality of stormwater runoff, but not its impact on receiving waters. Consequently, these models are designated as runoff models. As with the preceding model group (runoff and receiving water models), the quality portion of the runoff models is not adequate to meet the program objectives. Again, the quality relationships for runoff are based on general land utilization categories that do not specify the type of industry; hence, quality relationships addressing pollutant accumulation and washoff must be developed on an industry-by-industry basis. In addition to this limitation, the runoff models were not designed to simulate the impact of stormwater runoff on receiving waters. To simulate this impact, it is necessary to interface the runoff models with a receiving water model.

The EPA - Hydrocomp Agricultural Runoff Management Model (ARM) and Pyritic Systems: A Mathematical Model are designed to quantify and qualify stormwater runoff for the agricultural and mining industries, respectively. These models are described as specific industry models. As with the runoff models, the specific industry models cannot simulate the impact of stormwater flows on receiving waters. They must be interfaced with a receiving water model to simulate such impact. Since ARM was developed specifically for the agricultural industry, it is not necessary to modify the program quality relationships but only to calibrate and verify existing quality relationships with field data. On the other hand, Pyritic Systems: A Mathematical Model is designed for a drift (subsurface) mine. Extension of this model to surface mining (strip mining) requires both quantity and quality program modifications.

3.1.4 Background Review Conclusions

In this review, little information was found related to non-point sources from industrial sites. However, an evaluation of several industries indicated that runoff from material storage piles and runoff from accumulated materials due to fallout from fugitive and point source air emissions are the most probable industrial non-point sources.

The measurement methodology reviewed showed that, while there is much information concerning sampling of runoff in storm sewers and sampling receiving waters, overland runoff sampling and industrial runoff sampling must be further developed. The predictive methodology review yielded several models capable of being adapted to dynamically simulate the quantity and quality of stormwater runoff from industrial sites and its impact on the receiving waters.

Based on the conclusions of this task, the second and third tasks were designed as follows:

1. A field measurement survey (runoff and receiving water) to be designed and performed at two coal-fired utility plants.
2. A mathematical model to be developed capable of quantifying and qualifying non-point source industrial loading and its impact on receiving waters on an industry-by-industry basis, beginning with the utility industry.
3. The field survey data to be used to calibrate and verify the mathematical model.

Sections 3.2 and 3.3 summarize the field survey and model development, respectively.

3.2 Field Survey

3.2.1 Industry Selection(12)(13)

Electrical energy is generated from fossil and nuclear fuels at approximately 1,000 sites (1970) in the United States. Coal provides approximately 54% of the total heat input for electricity generation. In 1974 this amounted to a coal usage rate of 328 million metric tons (361 million short tons)* per year. Increasing demands for energy self-sufficiency are likely to push coal usage up to 454 million metric tons (500 million short tons) per year by 1990. Subsequently, coal storage, typically a 100-day supply, will increase from 100 million tons to 138 million tons. Land use for coal storage at electric facilities will increase to 81 million square meters (20,000 acres) from an approximate 1974 total of 58 million square meters (14,500 acres). Stormwater runoff from coal storage piles will also increase 38% to an estimated yearly total of 100,000-140,000 cubic meters per year (26 million to 37 million gallons per year).

These data show that the quantity of stormwater runoff will probably increase substantially by 1990. Its effect on the receiving bodies will become more pronounced as water quality improves through regulation of point sources. In addition, the industry faces proposed effluent limitations for drainage from coal storage piles. These indicated projections are the basis for the selection of the coal-fired utility industry for a sampling program.

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*In this report most units are reported first in the metric system and then in the English system in parentheses. However, in the modeling section, only English units are used since the models were originally developed in English units and no attempt was made to convert to the metric system.

3.2.2 Site Selection

Two coal fired steam electric generating facilities in Pennsylvania were chosen for the field study to identify and quantify runoff. Specific characteristics of each site are shown in Table 3-6.

The Warren Station of the Pennsylvania Electric Company in Warren, Pennsylvania is a small generating plant (84 MW) and is used primarily as a peaking facility. It is located on the Allegheny River below the Kinzua Dam. This dam regulates the river flow at approximately 56 cubic meters/sec (cms) (2,000 cubic feet/sec (cfs)) with an average velocity of 0.3 to 0.6 meters/sec (1-2 fps). Bituminous coal is delivered by truck to the station on a daily schedule from mines in Clarion County, Pennsylvania.

Figure 3-4 shows the basic site layout for the Warren Station. Coal pile runoff is channeled to a drain pipe by a drainage ditch that parallels unused railroad tracks next to the access road for the coal trucks. The drain pipe continuously drains small quantities of leachate during dry periods and substantial quantities of runoff during rainfall events. All runoff from the coal pile must pass through the drain pipe for discharge to the river. The paved access road is used by coal trucks to enter and leave the coal unloading area, and is covered with coal dust and earthen materials although the pavement is still visible through the accumulation. The road dust cover is washed off during rainfall events. The water drains across the road through a rockstrewn area of rubble approximately 12 meters (40 feet) wide to the river bank. There are several distinctly visible areas where this road dirt and coal dust are carried to the river. Vegetation is nonexistent in these drainage areas. Surface drains on paved

TABLE 3-6

CHARACTERISTICS OF THE TWO SAMPLING SITES USED IN THE SURVEY

Utility	Pennsylvania Electric Co.	Metropolitan Edison
Plant	Warren Station	Portland Station
Location	Warren, PA	Portland, PA
Capacity MW output, net	84	410
Coal		
Usage (metric tons/yr)	315,000 est. 1974	840,000 est. 1974
Source	Clarion Co., PA	PA & W. VA
Storage, metric tons	27,200	172,000
Sulfur %	1.84	1.47
Iron %	0.35	0.38
Manganese %	0.003	0.004
Aluminum %	0.56	0.37

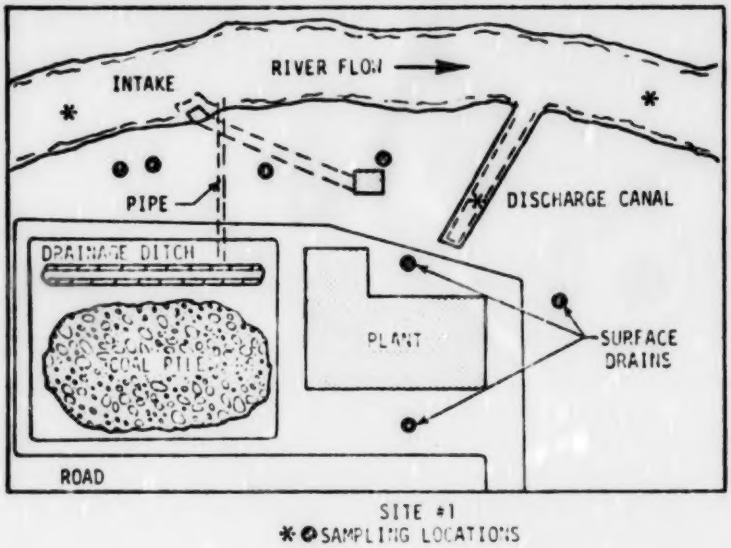

Figure 3-4: Site Layout with Sampling Locations - Warren Station of Pennsylvania Electric Co., Pennsylvania Electric Co., Warren, PA.

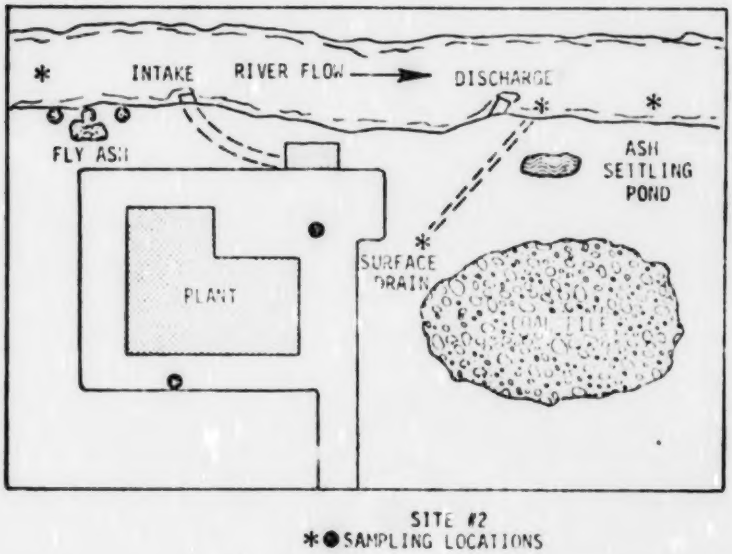

Figure 3-5: Site Layout with Sampling Locations - Portland Station of Metropolitan Edison Co., Portland, PA.

areas around the plant discharge into the main cooling water discharge canal. The surface drains are not effective in collecting stormwater due to the very irregular pavement surface.

The Allegheny River contained noticeable suspended material such as silt and detritus during the sampling period. The river water was generally close to air temperature with the downstream temperature approximately .5 to 1°C higher due to the discharge of plant cooling water at a rate of 3.6 cubic meters per second (57,000 gallons per minute).

The Portland Station of Metropolitan Edison Company is located in Portland, Pennsylvania on the Delaware River. This 410 MW station is much larger than the national average of 150 MW and is used as a baseload station. Bituminous coal is delivered by railroad car from Pennsylvania and West Virginia mines.

Figure 3-5 shows the basic site layout for the Portland Station. A substantial portion of the stormwater runoff is intercepted by the ash settling pond and never flows directly into the river. One sector of the coal pile runoff does go to a surface drain and is discharged with parking lot and road runoff into the river. Fly ash is kept on the north side of the plant (top left near river in Figure 3-5). There was very little fly ash stored during the sampling period. Stormwater runoff from this site washes directly into the river.

During the sampling period, the Delaware River had a flow rate of 300 cms (10,500 cfs) and an average velocity of .3 m/sec (1.0 fps). The water was generally very clear and much colder than prevailing air temperatures. As with the Warren site, the downstream river temperature was approximately .5 - 1.0°C higher due to the plant cooling water which was discharged near mid-river from a subsurface discharge tunnel at an average rate of 5.4 cubic meters per second (85,000 gallons per minute). The river height and turbidity changed rapidly with rainfall activity in its watershed.

3.2.3 Test Plan

A test plan was developed to fit the objective of quantifying the pollutants associated with stormwater runoff and their effect on the receiving waters. The test plan was designed to determine:

1. Background conditions in the receiving water prior to a storm event.
2. Volume of and pollutant concentrations in stormwater runoff as a function of time for the storm event.
3. Effect of the runoff on the receiving water during and after the storm event.

The following additional data gathering activities were incorporated to apply to the predictive model development:

1. Air temperature and humidity
2. Dustfall accumulation
3. River flow rates
4. Surface permeability.

To quantify the effect of stormwater runoff on the receiving body a sampling station was installed upstream of potential plant site effects and a second station was installed downstream of the plant. Theoretically, comparison of the data taken at these two sampling sites would show the effect of runoff on the river water quality. The sampling sites were to be placed at locations where representative samples could be taken with respect to the river cross-section and depth (i.e., samples having uniform chemical and physical properties). Placement of the downstream site was most critical because it had to be located at a position which allowed adequate mixing of the runoff in the river.

To develop the characteristics of the stormwater runoff it was necessary to intercept some amount prior to its entering the river. Each runoff basin was identified and sampling plugs were deployed to catch representative samples during a storm event. It was also necessary to quantify the flow rate of runoff to establish the time variable pollutant load on the river.

Velocity measurements were used to determine flow in pipes which collected runoff. In areas where sampling plugs had been used, the drainage area was determined and infiltration tests were performed to calculate the rate of percolation into the soil. Gross estimates of the total storm runoff flow were calculated using the total quantity of rain over the surface area minus the quantity of infiltration.

Composite samples were collected from the river sampling stations and runoff sites every 10 minutes for the first 90 minutes of a storm event to insure that the initial effects of the storm (including any possible "first flush" effects) were measured. For storms of longer than 90 minute duration, the sampling interval was extended to 30 minutes to avoid the collection of too many samples. Each sample was composited from 5 grab samples taken in a proportionally smaller time period. Thus, 5 two-minute grab samples were composited to give a 2 liter 10 minute sample, etc.

During dry periods before and after storms, samples were collected hourly from the upstream and downstream sites.

The pollutants analyzed in this program were total suspended solids (TSS), total dissolved solids (TDS), sulfate (SO_4), total iron (Fe), manganese (Mn), aluminum (Al), alkalinity (or acidity), and pH. Additionally, dissolved oxygen (DO) and temperature were monitored in the river.

The dustfall, surface permeability, and air temperature and humidity data collected were important to the predictive model development to define the dynamic behavior of the runoff with time.

To provide the most efficient use of manpower in the field, most analyses were intended to be performed in a field laboratory. Some specific analyses were done at the main laboratory when field analysis lag due to number of samples collected created sample aging difficulties, or when specialized equipment was needed.

3.2.4 Implementation

3.2.4.1 Warren Station

The field program was implemented without major difficulties. River samples were collected with an ISCO Model 16800L Sequential Sampler which was designed to provide backflushing before and after each sampling sequence to preserve the time integrity of the sample. The sampler was programmed to collect 200 ml grab samples every minute to provide a 2 liter composite every 10 minutes during the first 90 minutes of a rainfall period. From the 90th minute to the storm's end, the sampler was programmed to collect 70 ml every minute to give a 2 liter sample every half hour. During dry periods the sampler collected 70 ml every 2 minutes to give an hourly composite of 2 liters.

An upstream site was established 7.6 meters (25 ft) from the river's edge approximately 152 meters (500 ft) upstream of the cooling water intake. This location was well upstream of the runoff area from the access road. An air filled buoy was used to suspend the pH/DO (dissolved oxygen) and temperature sensors and the sample line at about half-depth, 1.2 meters (4 ft) above the bottom. Dissolved oxygen, pH and temperature were measured with a Model 101 ODEC Aqua Monitor. These data were recorded on a strip chart recorder during rainfall periods. A river depth profile was also made at this location as part of the predictive model development.

The downstream site was secured 46 meters (150 ft) from the river's edge approximately 152 meters (500 ft) downstream from the cooling water discharge-river interface. Although the turbulent main flow of the river appeared to be on the opposite side of the river, a mixing test indicated the sampling location was adequate. One dozen oranges were set adrift just above the upstream site and their journey was timed past several landmarks and past the downstream site. After traversing the rapids (approximately 75% of the distance from the upstream site to the downstream site), the oranges dispersed across the river fairly evenly. It was concluded that the downstream site was adequately placed to obtain representative data. An inflatable raft was used to suspend the sensor probe and sample line at 2 meters (7 ft), approximately mid-depth at the downstream site. The ISCO Sequential Sampler was mounted on the raft since the distance to shore was too far to run a sample line and maintain sample line integrity. An Orbisphere Dissolved Oxygen meter and chart recorder housed on shore in a tent were used to measure dissolved oxygen and temperature. River samples were taken in the same time sequence as the upstream samples. A recording rain gauge was installed at this site to record the rainfall rate during storm events. A river depth profile was also conducted at this location.

The runoff drainage areas were very well delineated by the appearance of vegetation between the road and the river. It was difficult to set the sampling plugs vertically into the rocky, rubble-strewn surface, so they were installed in the ground at a slight horizontal angle with the screened opening facing uphill. Approximately 50 plugs were distributed in the three main drainage areas and were kept covered with tape until a rainfall event started. A compositing bucket was placed under the coal pile drain pipe and an ISCO Sequential Sampler was used to collect runoff samples from this bucket. In operation, the sampler intake was continually plugged with push-along solids, and the sampler was replaced by manual sampling.

3.2.4.2 Portland Station

The objective for Portland was the same as for Warren, namely to characterize the coal pile runoff and its effect on the river. The test plan remained basically unchanged, but modifications in implementing it were necessary to reflect the specific differences between the two sites.

At Portland a small area of land north of the plant is used for fly ash storage during winter months. Runoff from this area drains under the plant fence and into the river. The upstream station was placed just upstream from this location approximately nine meters (30 ft.) from the shore. An air-inflatable raft was anchored at the upstream site to hold the sensors and sample lines at mid-depth, approximately three meters (10 ft.) below the surface. The swift current, local turbulence, and rocky bottom created great difficulty when personnel attempted to anchor the raft to its station. Broken and slipped moorings hindered the data gathering effort at this site throughout the program.

An ISCO Sequential Sampler was used to collect river samples in exactly the same fashion as at the Warren site. In place of the ODEC Aqua Monitor, an Orbisphere dissolved oxygen and temperature meter was used for those parameters. A battery powered chart recorder was used to record these data during a storm event.

The lower station was established approximately 30 meters (100 ft.) downstream from the cooling water discharge tunnel, approximately 230 meters (750 ft.) from the upstream site. An identical instrumentation and sampling arrangement as at the upstream site was used.

The coal pile runoff drained to both the ash pond and the storm sewer. A portion of the runoff to the storm drain was intercepted for sampling. Initially, an ISCO Sequential Sampler was installed in the storm drain but large coal particles continually plugged the sample intake line and pump. To solve this problem, sampling plugs were placed in an array around the storm sewer inlet. Approximately 25 sampling plugs were also deployed in the drainage basin of the fly ash storage area. As with the sequential samplers, samples were collected every ten minutes for the first 90 minutes, and half hourly for the duration of the storm event.

During the one storm event sampled at Portland, river conditions (swift current and rising level) hampered river sampling since the only access to the river sites was by boat. Due to the turbidity of the runoff, flow measurements were unsuccessful. The quantity and color of the solids in the runoff masked the dyes used as flow-timing indicators. The storm drains were partially clogged in several locations so that velocity markers could not be used. A second storm could not be sampled at this site due to a prolonged dry spell, followed by the beginning of cold weather and freezing conditions.

3.2.4.3 Analytical Procedures

Analysis of samples for pH, sulfate and alkalinity was performed on site in a field laboratory to guard against the effects of sample degradation. Where extreme values were noted, the samples were returned to the chemical laboratory in Wethersfield, Connecticut for further analysis. Samples were also returned to this laboratory for analysis of total dissolved and suspended solids, acidity, total iron, aluminum, and manganese. Sulfate samples which required large dilutions were also returned to the laboratory. All samples were preserved by appropriate means for transportation as shown in Table 3-7.

For analysis of alkalinity, appropriate sample aliquots were titrated with standard 0.02 N sulfuric acid using methyl orange as an indicator. The titration is complete at a pH of 4.0. For samples with pH values of less than 4.0, acidity titrations were performed on appropriate aliquots with standard 0.1 N sodium hydroxide as the titrant to

TABLE 3-7

PRESERVATION AND ANALYTICAL METHODS USED FOR SAMPLE ANALYSES

Parameter	Preservative	Concentration Technique	Analytical Method*	Limit of Detection
pH	None	None	Determined on site; Electrometric	0.1
Total Dissolved Solids	Cool to 4°C	None	Filtration; Evaporation; Gravimetry	0.1 mg/1
Total Suspended Solids	Cool to 4°C	None	Filtration; Gravimetry	0.1 mg/1
Sulfate	Cool to 4°C	None	Turbidimetry	0.5 mg/1
Alkalinity/Acidity	Cool to 4°C	None	Titrimetry	1 mg/1
Total Iron	HNO_3 to pH <2	Evaporation	Atomic Absorption; Air-Acetylene Flame	0.05 mg/1
Total Aluminum	HNO_3 to pH <2	Evaporation	Atomic Absorption; Nitrous Oxide-Acetylene Flame	0.2 mg/1
Total Manganese	HNO_3 to pH <2	Evaporation	Atomic Absorption; Air-Acetylene Flame	0.012 mg/1

* Analyzed in accordance with procedures described in Standard Methods for the Examination of Water and Wastewater, 14th edition, APHA, AWWA, WPCF, 1975.

a pH of 8.3. Because samples analyzed for acidity were highly colored, measurement by pH meter was used to identify the endpoint.

The turbidimetric method was used to determine sulfate concentrations. Standard curves were generated daily from known sulfate concentrations. Upstream and downstream samples posed no unusual problems. Direct runoff samples, however, were found to have high sulfate concentrations. For these samples large dilutions were necessary to make samples fall within a workable range. The runoff samples from both sites had high color and turbidity backgrounds. Turbidity measurements were made prior to the development of the barium sulfate suspension and this background value was subtracted from the value after the barium suspension formed.

Total dissolved and total suspended solids were determined by filtering an appropriate sample aliquot through a tared Gooch crucible containing a standard Reeve Angel type 934 AH glass fiber filter disc. Weighing of the material remaining on the filter disc after drying at 103°C is a measure of total suspended solids. The filtrate is placed in a tared evaporating dish. The material remaining in the dish after evaporation and drying at 103°C is a measure of the dissolved solids. No significant problems were encountered in performing this analysis.

In order to determine total iron, aluminum and manganese, it was necessary to concentrate the samples. Concentration factors varied from two to four depending on the nature of the sample. The concentration was accomplished by digestion using nitric acid. Measurement was made by atomic absorption spectrophotometry using an air-acetylene flame for iron and manganese and a nitrous oxide-acetylene flame for aluminum. Standard curves were generated with each series of analysis by using known concentrations of the appropriate metal.

For the most part pH was determined on site. In instances where time was a limiting factor, the samples were returned to the laboratory for analysis. Before pH measurements were made, the meter was standardized using three buffers of pH = 4.01, 7.00, and 9.18.

Dustfall samples were collected daily from a measured ground area. These samples were returned to the laboratory for analysis of leachable material. Each sample was first weighed to determine the total particulate of dustfall. The samples were then leached in a measured amount of distilled-deionized water by constant rotation over a seventy-two hour period. The resulting water solution after filtration was analyzed for pH, total dissolved solids, sulfate, total iron, manganese and aluminum. The analysis was then conducted in the same manner as that described for the water samples. With the exception of pH, results were reported as percent dry weight leachable material of the entire dustfall sample.

3.2.4.4 Quality Control of Analytical Work

At the time of collection each sample was assigned a unique identification number which referred to the sampling location, the day sampled and the time. An inventory of all samples plus the required analysis was then prepared for submission of the set of samples to the chemical laboratory. The supervisor of the chemical laboratory received all samples for analysis, and checked to insure agreement between the actual sample bottles and the accompanying inventory log. The supervisor then assigned an analysis number to the set of samples and scheduled the samples for work-up by laboratory chemists and technicians.

Once analysis of the samples was completed, all final results and raw data were returned to the supervisor who reviewed them for accuracy. The supervisor then selected, at random, ten percent of the set of samples for re-analysis and returned them to the laboratory. Final results and raw data were again returned to the supervisor for review and comparison with previous results for reproducibility. The supervisor then reported all final results to the project manager. A file is maintained in the office of the chemical laboratory supervisor which contains all pertinent data for the specific project such as final results, calculations and project memorandums.

Field analysis data were handled in much the same manner. They were returned to the chemical laboratory for review for accuracy. Where possible, the supervisor submitted to the in-house laboratory ten percent of the samples analyzed in the field for repeat analysis in order to determine reproducibility. The supervisor then approved the field results for use by the project manager.

All water and wastewater analyses were performed according to procedures described in Standard Methods for the Examination of Water and Wastewater, 14th edition, APHA, AWWA, WPCF, 1975 and Methods for Chemical Analysis of Water and Wastes, Methods Development and Quality Assurance Research Laboratory, U. S. Environmental Protection Agency, 1974.

An inventory file is maintained by the chemical laboratory supervisor of all instrumentation in the laboratory. This file documents instrument performance and contains such information as manufacturer, installation date and serial number. Instrument servicing is documented in this file, including date of the service call, who performed the service and how the problem was corrected. For analytical balances, this file serves to document annual service to insure performance within manufacturer's specifications. Balance files also record calibration by weight traceable to the National Bureau of Standards.

Each time an analysis is run, a standard curve is generated for instrument calibration. For atomic absorption work a copy of each curve is kept with the instrument to indicate possible trends in instrument performance such as hollow cathode lamp deterioration. Copies of all standard curves are also kept in the appropriate project file along with the raw data.

The laboratory maintains a supply of stock standard solutions for dilution on a daily basis as needed. Stock standard solutions are clearly labeled with date of preparation, concentration and discard dates.

Monitoring the laboratory's performance is accomplished in several ways. Periodically during the course of the year, TRC requests from the Regional Quality Control Coordinator, U. S. Environmental Protection Agency, reference samples from any of the following series: nutrient analyses, demand analyses, mineral analyses, mercury analyses or trace metals analyses. Once received, these samples are analyzed along with any set of similar samples presently in-house. Results are compared with quoted concentrations for accuracy and corrective action is taken when necessary.

As part of maintaining an approved Public Health Laboratory license with the Connecticut State Department of Health, TRC is required to participate in its proficiency test program. This consists of periodic mailings of reference samples similar to those described above which must be analyzed within a specified period of time. Results are returned to the state laboratory for statistical analysis. A representative from the State Department of Health also inspects the facility on an annual basis. The laboratory condition is documented and this record is kept on file at the Health Department with a copy sent to the laboratory supervisor at TRC.

3.2.5 Results of Field Survey

Despite the less than desirable amount of storm activity at Warren and Portland, enough data were collected to show some interesting effects. From the analyses of the coal pile runoff and receiving waters during dry and wet weather, some general characterizations can be made.

The laboratory analyses of the field data during dry and wet periods at all sampling stations show a broad range of values. These ranges of values were substantial enough to mask any apparent relationships between sites and sampling locations. Several statistical summaries have been prepared for selected pollutants during dry and wet periods at the two sampling locations in the receiving body. These summaries included arithmetic means, standard deviation, coefficients of variation and best estimates of variance to provide the statistical basis for comparisons of results. These tests were performed within 95% confidence limits for the selected pollutants of interest. The 95% confidence limits were defined as:

$$\bar{X} \pm t_{\nu, \frac{\alpha}{2}} \sqrt{\frac{s^2}{n}}$$

where:

$\bar{X}$ = arithmetic mean of data set with n elements

t = percentile of the 't' distribution at ν degrees of freedom and $(1 - \alpha)$ confidence limits

s^2 = best estimate of sample variance of n elements in data set.

The calculations were done using two-tailed tests with non-detected values distributed proportionally between 0 and the limit of detection for the specific pollutant. It was assumed that the distribution of the data was approximately similar to a normal distribution. A plot of several sets of data on normal probability coordinates confirmed this assumption.

Runoff data are presented as time averages and no attempt was made to evaluate them statistically.

Reliable river dissolved oxygen data were not obtained at either site. Equipment malfunction and defective sensors were the primary cause of the problems at both sites.

3.2.5.1 Warren Station Data

Table 3-8 shows the range of pollutant concentrations at the various sampling locations at the Warren Station. The most significant

TABLE 3-8

RANGE OF POLLUTANT CONCENTRATION AT THE SAMPLING LOCATIONS AT WARREN STATION OF PENNSYLVANIA ELECTRIC CO., WARREN, PA AUGUST - SEPTEMBER, 1976

Pollutant	RANGE OF POLLUTANT CONCENTRATIONS, mg/l					
	Upstream		Downstream		Coal Pile Discharge Pipe	
	Dry	Wet	Dry	Wet	Dry	Wet
Total Suspended Solids	1 - 21	2 - 5	1 - 11	2 - 12	12 - 19000	1700 - 13000
Total Dissolved Solids	100 - 170	60 - 130	80 - 180	-	2300 - 21700	2300 - 115000
Iron	.14 - .40	.09 - .17	.06 - .34	.09 - 1.03	160 - 23500	700 - 1400
Aluminum	N.D.[1]	N.D.[1]	N.D.[1]	N.D.[1] - 26.6	20 - 1800	70 - 100
Manganese	.013 - .090	.025 - .040	N.D.[2] - .040	.030 - .060	2 - 100	9 - 15
Sulfate	11 - 20	12 - 17	11 - 22	12 - 24	90 - 57000	1600 - 2700
Total Alkalinity @ $CaCO_3$	38 - 48	38 - 42	36 - 45	40 - 41	-	-
Total Acidity @ $CaCO_3$	-	-	-	-	200 - 38000	1900 - 2900
pH	6.77 - 7.80	6.60 - 6.76	6.77 - 7.60	6.36 - 6.87	1.48 - 3.37	2.35 - 3.36

[1] None detected, < 0.2 mg/l

[2] None detected, < 0.012 mg/l

observation is that the pollutants in the coal pile discharge pipe are more concentrated during dry weather (leachate) than wet (runoff), as would be expected.

The downstream pH values do appear lower under both wet and dry sampling conditions. More data are necessary to establish a cause and effect relationship between runoff and pH behavior in the river.

Table 3-9 presents the mean concentrations with 95% confidence limits for selected pollutants in the receiving body. These data show the extreme variability in the measurements made upstream and downstream. Generally, the upstream and downstream sites appear to have similar pollutant concentrations but a more detailed analysis was made using Student's 't' and the 'F' distribution tests.

Table 3-10 shows the results of the 't' and 'F' tests for comparisons of data from the upstream and downstream sites during dry and wet periods. The data used in 't' and 'F' tests can be found in Appendix A (Table A-1). There is no statistical difference between mean pollutant concentrations at the upstream and downstream sites during dry weather. The sample variances for TSS and Fe during the dry period at both sites were statistically different.

Student's 't' tests were also performed using 60% confidence limits since no trends appeared using the 95% confidence limits. Comparisons of the 't' test results did show for 60% confidence limits: Statistically significant difference between upstream-'dry' and upstream-'wet', downstream-'dry' and downstream-'wet', downstream-'wet' and upstream-'wet' for a majority of the pollutants. The statistically significant differences in these

TABLE 3-9

MEAN POLLUTANT CONCENTRATIONS WITH 95% CONFIDENCE LIMITS IN THE ALLEGHENY RIVER AT WARREN STATION OF PENNSYLVANIA ELECTRIC CO., WARREN PA
AUGUST - SEPTEMBER, 1976

Pollutant	POLLUTANT CONCENTRATION, mg/l			
	Upstream		Downstream	
	Dry	Wet	Dry	Wet
TSS	8.11 ± 2.26	7.25 ± 3.18	4.13 ± 2.04	5.50 ± 2.71
SO_4	13.89 ± 0.84	15.09 ± 0.94	13.83 ± 1.45	16.65 ± 2.25
Fe	0.23 ± 0.02	0.12 ± 0.03	0.21 ± 0.09	0.39 ± 0.27
Mn	0.028 ± 0.005	0.032 ± 0.003	0.023 ± 0.005	0.043 ± 0.012
Alk	41.65 ± 0.85	40.33 ± 0.94	39.33 ± 0.89	40.30 ± 0.34

95% confidence limits = $\bar{x} \pm t_{\nu,.025}\sqrt{\frac{s^2}{n}}$

TABLE 3-10

COMPARISONS OF MEAN VALUES & VARIANCES WITHIN 95% CONFIDENCE LIMITS AT UPSTREAM & DOWNSTREAM SITES DURING DRY & WET SAMPLING PERIODS
WARREN, PENNSYLVANIA
AUGUST - SEPTEMBER, 1976

Pollutant	Degrees of Freedom	t Test	Difference Between Means	Is Difference Between Means Significant?	Critical 'f' for 95% Confidence	'F' Ratio	Is Difference Between Variances Significant?
			UPSTREAM DRY - DOWNSTREAM DRY				
TSS	50	7.47	3.98	No	2.69	3.38	Yes Upstream > Downstream
SO_4	44	3.06	0.06	No	2.53	0.55	No
Fe	52	0.138	0.02	No	2.416	0.12	Yes Upstream < Downstream
Mn	51	0.015	0.005	No	2.422	2.00	No
Alk	65	2.59	2.32	No	2.173	1.72	No
			UPSTREAM WET - DOWNSTREAM WET				
TSS	16	8.45	1.75	No	4.82	1.88	No
SO_4	19	4.57	1.56	No	3.96	0.196	Yes Upstream < Downstream
Fe	17	0.495	0.27	No	4.36	0.011	Yes Upstream < Downstream
Mn	18	0.019	0.011	No	4.72	0.10	Yes Upstream < Downstream
Alk	17	1.86	0.03	No	4.10	6.52	Yes Upstream > Downstream
			UPSTREAM WET - UPSTREAM DRY				
TSS	45	9.26	0.86	No	2.50	0.43	No
SO_4	37	2.91	1.20	No	2.57	0.41	No
Fe	43	0.086	0.11	Yes	2.52	0.33	No
Mn	44	0.017	0.004	No	2.42	0.10	Yes Wet < Dry
Alk	50	3.81	1.32	No	2.44	0.20	Yes Wet < Dry
			DOWNSTREAM WET - DOWNSTREAM DRY				
TSS	21	6.71	1.37	No	3.38	0.77	No
SO_4	26	4.96	2.82	No	2.98	1.16	No
Fe	26	0.42	0.18	No	3.01	3.62	Yes Wet > Dry
Mn	25	0.0202	0.0200	Marginal	3.10	2.00	No
Alk	32	2.80	0.97	No	2.73	0.05	Yes Wet < Dry

data are mitigated by the comparisons of upstream dry and downstream dry data which show unexpected differences for TSS, Mn and alkalinity. A summary of these comparisons is given in Appendix A, Table A-3.

Table 3-11 shows the characteristics of the coal pile leachate during the dry weather sampling. The site layout with the drainage ditch and pipe facilitated collecting leachate samples. These data show that the leachate is concentrated and extremely acidic. The flow rate was very low and no effect on the river was detected. The total suspended and dissolved solids concentrations seem to be dependent upon the length of time since the previous rain. As this time increases, the concentrations decrease. The color of the leachate remained amber during the dry period.

Table 3-12 shows the rainfall event data collected at Warren, Pennsylvania. Other than suspended and dissolved solids, the pollutant concentrations were fairly consistent between the two storms. Since the first storm was a short-term, moderately intense cloudburst, it was not possible to collect samples quickly enough to show any immediate effect of the runoff on the river. From this storm it was verified that the plug locations for sampling the surface runoff were adequate. The second storm lasted much longer and provided the bulk of data for the data evaluation and conclusions.

Table 3-13 presents the characteristics of the coal pile runoff and the surface runoff from the access road during the second storm event. At the start of the storm, the "first flush" effect with its higher pollutant concentrations can be seen. These values generally declined through the rainfall period. Some perturbations do appear

TABLE 3-11

CHARACTERISTICS OF COAL PILE LEACHATE-DRY WEATHER AT WARREN STATION OF PENNSYLVANIA ELECTRIC CO., WARREN, PA AUGUST - SEPTEMBER, 1976

Date	Hours Since Last Rain	Pollutant Concentration, mg/1								Discharge Flow Rate lpm (gpm)
		TSS	TDS	SO_4	Fe	Al	Mn	Acidity	pH	
8/25/76	250	200	40,000	57,000	23,500	1,800	100	18,000	2.4	1.5 (.39)
8/27/76	17	18,700	82,600	45,000	14,000	1,400	70	27,000	2.1	1.5 (.39)
9/16/76	505	12	21,700	25,000	9,700	1,100	70	37,600	1.5	1.4 (.39)

TABLE 3-12

CHARACTERISTICS OF RAINFALL EVENTS AT WARREN STATION OF PENNSYLVANIA ELECTRIC CO., WARREN, PA

AUGUST - SEPTEMBER, 1976

Site	Storm	Elapsed Time min	Total Precipitation cm (in)	POLLUTANT CONCENTRATION, mg/1						
				TSS	TDS	SO_4	Fe	Mn	Al	pH
Warren	1 8/26/76	20	2.8 (0.11)	0.9	1679.	14.9	21.5	0.275	3.18	3.90
	2 9/17/76	430	8.9 (0.35)	1.5	11.	12.4	19.8	0.304	2.71	4.15

TABLE 3-13

CHARACTERISTICS OF COAL PILE & ACCESS ROAD RUNOFF
DURING SECOND STORM EVENT AT
WARREN STATION OF PENNSYLVANIA ELECTRIC CO., WARREN, PA
17 SEPTEMBER 1976

TIME	POLLUTANT (mg/1)														
	COAL PILE RUNOFF							DISCHARGE FLOW RATE	AVERAGE SURFACE RUNOFF						
	TSS	TDS	SO_4	FE	AL	MN	ACIDITY	lpm (gpm)	TSS	TDS	SO_4	FE	AL	MN	ACIDITY
1000 - 1015 - Rain Start	9800	4600	2300	900	100	40	3200	22 (5.8)	11200	2800	1000	100	100	10	1700
1015 - 1030	4200	3300	2300	-	-	-	2600		1400	900	600	200	40	5	600
1030 - 1045	6400	2400	1600	700	90	10	3100		4900	900	500	200	30	4	600
1045 - 1100	11400	2400	1800	1400	70	10	2000		4400	600	900	-	40	5	500
1100 - 1115	5000	2500	2100	700	80	10	2200	20 (5.3)	3700	500	400	300	50	5	300
1115 - 1130	1700	3700	2100	500	-	-	2900		3000	400	200	200	-	-	100
1130 - 1200	1400	3800	2700	-	-	-	-	20 (5.3)	1100	600	600	-	-	-	500
1200 - 1230	1600	3100	1700	300	-	-	-		3100	700	500	200	40	7	500
1230 - 1300	1700	3000	1000	200	-	-	-		1700	700	-	-	-	-	-
1300 - 1330	1700	-	-	-	-	-	-		1500	-	-	-	-	-	-
1330 - 1500 - Rain End	23000	500	200	-	-	2	500	17 (4.5)	2300	1400	1000	400	70	6	1000

since the rain did not fall at a constant rate throughout the day. All measured pollutant values are lower during rain than during dry periods. When a comparison of the data in Tables 3-11 and 3-13 is made, it appears that water stored in the coal pile solubilizes various impurities in the coal and leaks out very slowly. Rainfall washes out the stored water within the pile, thus greatly diluting the impurities.

It was noticed that, in comparing the coal pile runoff with the dry weather leachate, the mass loading per unit time of all pollutants except suspended solids, is greater during the dry period. A closer examination of this behavior is warranted.

The surface runoff shows much similarity with the coal pile runoff as the contaminant levels decreased through the storm's duration. Black granular material was observed on the access road and runoff surfaces during the field work and the data do indicate the presence of similar contaminants as in the coal pile runoff. The coal pile and surface runoff responded very quickly to rainfall intensity. The ground around the coal pile and the surface runoff areas had a very low porosity, practically zero. Within minutes after the rain stopped, the runoff declined to zero and the coal pile discharge returned to its prior appearance and flow rate.

The 't' and 'F' tests presented in Table 3-10 show no statistically significant effect of runoff on the river. However, in the case of sulfate, iron, manganese and alkalinity, the sample variances were significantly different. In the cases where differences were noted, except for total alkalinity, the upstream sample variance was lower than downstream. This difference is partly related to the sampling locations.

Although both locations were as representative of the river's cross-section as could be determined, it is likely that the downstream site contained a greater number of anomalies. The river was very wide at this point with a greater probability for peculiarities in flow patterns due to the delta formation, rapids and the large island just upstream of the site.

In a comparison of each river site during the wet and dry periods, the data show only two statistically significant differences. At the upstream site the data indicate a difference in the mean concentration of iron. The dry period had much higher concentrations than the wet period. There was a marginal difference in manganese concentrations during wet and dry periods at the downstream site. In comparing these 'wet' versus 'dry' variances with upstream versus downstream variances, it can be seen that they are partly the result of differences in the characteristics of each site as well as differences created by the rainfall events.

3.2.5.2 Portland Station Data

Table 3-14 shows the range of values for each pollutant at the Portland Station sampling sites. These ranges are similar to those measured at the Warren Station sites. They commonly vary by up to an order of magnitude.

The pH values during the short sampling period at Portland appear to cover a higher range downstream from the plant contrary to pH values observed at Warren.

TABLE 3-14

RANGE OF POLLUTANT CONCENTRATION AT THE SAMPLING LOCATIONS AT PORTLAND STATION OF METROPOLITAN EDISON CO., PORTLAND, PA

OCTOBER 1976

Pollutant	RANGE OF POLLUTANT CONCENTRATION, mg/1							
	Upstream		Downstream		Coal Pile Runoff		Fly Ash Pile Runoff	
	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
Total Suspended Solids	3 - 33	10 - 20	2 - 43	4 - 11	-	220 - 3800	-	840 -15200
Total Dissolved Solids	43 - 72	62 - 89	38 - 71	46 - 67	-	600 - 7500	-	730 - 2500
Iron	.18 - 2.0	.18 - .45	.18 - 1.4	.18 - .63	-	18 - 400	-	73 - 245
Aluminum	N.D.[1]- .63	N.D.[1]	N.D.[1]- 1.25	N.D.[1]	-	2.75 - 88	-	63 - 200
Manganese	.03 - .14	N.D.[2]-.03	.01 - .18	N.D.- .03	-	3.75	-	.03 - 25
Sulfate	10 - 18	9 - 22	5 - 12	5 - 11	-	380 - 6000	-	100 - 1600
Total Alkalinity @ $CaCO_3$	12 - 25	16 - 19	12 - 21	16 - 20	-	-	-	-
Total Acidity @ $CaCO_3$	-	-	-	-	-	300 - 4600	-	11 - 800
pH	6.2 - 6.8	6.5 - 6.8	6.3 - 7.2	6.6 - 7.2	-	2.35 - 3.10	-	2.72 - 3.06

[1] None detected, < 0.2 mg/1

[2] None detected, < 0.012 mg/1

Table 3-15 shows the 95% confidence limits for the upstream and downstream sites during dry and wet periods. As was true with the Warren sampling data, most of the Portland data at each river sampling site seems to be similar during both the 'dry' and 'wet' sampling periods. A comparison of Portland data with Warren data indicates that the Delaware River at Portland has higher suspended solids, iron and manganese, but lower alkalinity and similar sulfate.

Student's 't' and 'F' distribution tests of significance were performed to establish any apparent relationships between sites and sampling locations (see Table 3-16). The tests were based on the data shown in Appendix A (Table A-2).

As expected, the 't' and 'F' tests on the dry weather data show no significant differences between means or variances at upstream and downstream sites. The sample variances at Portland were noticeably greater than at Warren, due possibly to the smaller sample size at Portland. The intrinsic characteristics of each river's behavior, as well as the sampling techniques used, are also undefined contributors to the sample variance.

Student's t't tests using 60% confidence limits were also performed on the Portland data since no trends appeared using the 95% confidence limits. The 't' test results using 60% confidence limits showed:

1. Statistically significant differences between downstream 'dry' and downstream 'wet' (all five pollutants), upstream 'dry' and upstream 'wet' (three pollutants), upstream 'wet' and downstream 'wet' (three pollutants).
2. No statistically significant differences between upstream 'dry' and downstream 'dry' except for SO_4.

TABLE 3-15

MEAN CONCENTRATIONS WITH 95% CONFIDENCE LIMITS FOR SELECTED POLLUTANTS AT THE PORTLAND STATION OF METROPOLITAN EDISON CO., PORTLAND, PA OCTOBER 1976

Pollutant	POLLUTANT CONCENTRATION, mg/l			
	Upstream		Downstream	
	Dry	Wet	Dry	Wet
TSS	12.72 ± 4.86	13.54 ± 5.91	11.66 ± 6.96	7.39 ± 2.20
SO_4	12.86 ± 1.31	14.25 ± 6.12	10.10 ± 1.10	8.15 ± 1.31
Fe	0.56 ± 0.22	0.30 ± 0.10	0.56 ± 0.18	0.43 ± 0.21
Mn	0.051 ± 0.016	0.020 ± 0.010	0.055 ± 0.020	0.016 ± 0.006
Alk	16.07 ± 1.82	17.60 ± 1.42	15.59 ± 1.26	16.38 ± 0.43

TABLE 3-16

COMPARISONS OF MEAN VALUES & VARIANCES WITHIN 95% CONFIDENCE LIMITS AT UPSTREAM & DOWNSTREAM SITES DURING DRY & WET SAMPLING PERIODS PORTLAND STATION

Pollutant	Degrees of Freedom	t Test	Difference Between Means	Is Difference Between Means Significant?	Critical 'f' for 95% Confidence	'F' Ratio	Is Difference Between Variances Significant?
UPSTREAM DRY - DOWNSTREAM DRY							
TSS	27	17.48	1.06	No	2.96	0.378	No
SO_4	35	3.32	2.76	No	2.62	1.18	No
Fe	37	0.55	0	No	2.53	1.21	No
Mn	36	0.05	0.004	No	2.55	0.50	No
Alk	29	4.20	0.48	No	2.86	1.65	No
UPSTREAM WET - DOWNSTREAM WET							
TSS	11	9.82	6.15	No	5.52	3.26	No
SO_4	16	7.34	6.10	No	4.12	5.16	Yes Upstream > Downstream
Fe	16	0.631	0.13	No	4.04	0.091	Yes Upstream < Downstream
Mn	16	0.044	0.004	No	4.04	1.00	No
Alk	11	2.22	1.22	No	5.52	4.81	No
UPSTREAM WET - UPSTREAM DRY							
TSS	16	17.40	0.82	No	4.12	0.350	No
SO_4	20	7.02	1.39	No	3.73	3.76	Marginal Dry < Wet
Fe	22	0.791	0.26	No	3.44	0.052	Yes Dry > Wet
Mn	21	0.058	0.031	No	3.50	0.100	Yes Dry < Wet
Alk	17	6.52	1.53	No	4.00	0.131	No
DOWNSTREAM WET - DOWNSTREAM DRY							
TSS	22	20.29	4.27	No	3.29	0.041	Yes Dry > Wet
SO_4	31	3.38	1.95	No	2.72	0.861	No
Fe	31	0.568	0.13	No	2.73	0.688	No
Mn	31	0.055	0.039	No	2.73	0.05	Yes Dry > Wet
Alk	23	3.79	0.79	No	3.22	0.045	Yes Dry > Wet

A comparison of the 't' test results with 60% and 95% confidence limits is shown in Appendix A, Table A-3.

Based on these results, there is some justification that runoff from the Portland plant was having an effect on the TSS levels and the alkalinity of the river. The alkalinity decreased indicating that the acidic runoff was having an effect. However, TSS concentration was lower, probably due to the cooling water discharge rather than the storm runoff.

The parameters associated with the single rain event at Portland are presented in Table 3-17. The rain at Portland had noticeably lower concentrations of iron, manganese and aluminum than at Warren. Other parameters were similar between the two sites.

When compared with the Warren data, the coal pile runoff has substantially lower concentrations of pollutants (see Table 3-18). In part, this is the result of the different sampling procedures required at each site as determined by the site layout. At Warren, the entire runoff from the coal pile was intercepted by a drainage ditch. At Portland, only a small portion of the total runoff was captured from a coal pile that was much farther from the sampling location. Collection of samples had to be made near the surface drain since the terrain near the pile was uncertain and the survey objective was to examine only the portion draining to the river. It is also possible that the distance between the coal pile and the surface drain allowed the soil to filter pollutants out of the runoff.

Compared with Warren, the response of runoff flow at Portland was much slower (i.e., there was a greater time lag) with respect to the rainfall intensity. The runoff did have sufficient force to transport

TABLE 3-17

CHARACTERISTICS OF THE RAINFALL EVENT AT
PORTLAND STATION OF METROPOLITAN EDISON CO., PORTLAND, PA
20 OCTOBER 1976

Site	Storm	Elapsed Time min	Total Precipitation mm(in)	POLLUTANT CONCENTRATION, mg/1						
				TSS	TDS	SO	Fe	Mn	Al	pH
Portland	10/20/76	810	39.2 (1.55)	2.	102	9.7	0.18	ND[1]	ND[2]	5.70

[1] None Detected, < 0.012 mg/1
[2] None Detected, < 0.2 mg/1

TABLE 3-18

CHARACTERISTICS OF COAL PILE & FLY ASH AREA RUNOFF DURING THE RAINFALL EVENT AT PORTLAND STATION OF METROPOLITAN EDISON CO., PORTLAND, PA
20 OCTOBER 1976

TIME	POLLUTANT (mg/1)													
	COAL PILE RUNOFF							FLY ASH AREA RUNOFF						
	TSS	TDS	SO_4	FE[1]	AL[1]	MN[1]	ACID-ITY	TSS	TDS	SO_4	FE	AL	MN	ACID-ITY
0700 - 0730	240	-	-	20	8	0.4	290	200	200	100		-	-	10
0730 - 0800	300	-	-	40	19	0.8	300	400	400	200	-	-	-	200
0800 - 0830	350	500	500	-	-	-	-	-	-	-	-	-	-	-
0830 - 0900	-	600	500	60	15	0.6	370	-	-	-	-	-	-	-
0900 - 1000	230	600	400	80	15	0.5	300	800	1300	-	-	-	-	400
1000 - 1100	280	3400	2000	400	50	1.8	2400	1200	1700	1100	100	60	2.3	700
1100 - 1200	-	-	-	-	-	-	-	6600	2200	1400	200	140	1.3	900
1200 - 1300	-	-	-	-	-	-	-	-	-	-	-	-	-	
1300 - 1400	1700	4200	-	300	30	1.6	-	-	-	-	-	-	-	
1400 - 1500	2200	7500	6000	-	-	-	4600	14000	1800	1200	200	200	0.2	500
1500 - 1700	2200	4800	-	200	50	2.5	-	2300	1000	800	150	60	1.2	600
1700 - 1830	3800	4300	2600	400	90	2.5	2600	1200	800	700	-	-	-	500

[1] Concentrations as entering the river

quite large (1-5 mm) particles. Plug sampling replaced automatic sampling after the sequential samplers became inoperative from being jammed with these particles. The plug collectors, even with screen covers, did collect some of the push-along particles that the sequential sampler did not. This could explain the change of pollutant concentrations at 1000 hours. The large particles were removed from the sample within a few hours prior to returning the samples for analysis, but their partial dissolution could explain the increase in concentrations. There is also the possibility that rainfall intensities, with their effect of washing out more of the soluble material, could have caused this increase. The fly ash pile area released much higher concentrations of suspended and dissolved solids into the river than the coal pile runoff released. Acidity, sulfate, and metals concentrations were lower. The flow from the coal pile and the fly ash storage area could not be quantified with any success. If the study had continued for another rain event, semi-permanent weirs would have been installed to eliminate this problem.

As indicated in Table 3-16, the runoff from the coal pile and fly ash area did not have any measurable effect on the river. Statistically, there was no measured difference at either site during the wet and dry sampling periods. These observations must be mitigated by the small sample size as well as statistically significant differences in the sample variances.

The sample variances at Portland, except for dry weather comparisons, are statistically different for each of the compared sample sets. There is no apparent consistency to these differences with respect to pollutant, site, or sampling condition. It can be concluded that a rain event does introduce an additional degree of variability to the data. The Portland 'dry' data shows no difference in variance between samples taken at the two sampling sites. This does contrast with the Warren 'dry' data which did have some variances. It is inferred that the sampling location is another factor affecting the Warren data but not the Portland data, where the river flow pattern was less complex. The sample variances are similar at Warren and Portland for each pollutant with few exceptions, despite the slight differences in sample size. Total suspended solids and iron seem to have the greatest degree of variation at both sites under the different sampling conditions.

The Warren and Portland Station data do not show any coal pile runoff impact on the river. It appears sample sizes may be too small to indicate a definitive conclusion of the runoff effects at either Warren or Portland. The data certainty can be improved with a larger data base and some improvement in sample variances.

3.3 Model Development

Prior to the work described in this report, a mathematical model had not been developed to quantify and qualify stormwater runoff and to determine the impact of such runoff on receiving waters for specific industries, with the exception of agriculture and mining. The objective of this program was to develop such a mathematical model capable of quantifying and qualifying non-point source industrial loadings and their impact on receiving waters. To increase model utilization, the model was to be inherently flexible so that it could be applied to various types of industry with only minor modifications.

To effectively satisfy the above objective, existing mathematical models were reviewed (Section 3.1.3) and the model best able to meet the study objective with the least amount of modification was chosen for development and adaptation. The model selection, modification, development, and testing program, and the results are discussed in this section.

3.3.1 Model Selection

Of the ten models reviewed (Section 3.1.3), the simplest, most flexible model requiring the least amount of modification with the capability to quantify and qualify stormwater runoff from industry and to determine the impact of such runoff on receiving waters was the Short Stormwater Management Model(14) and Receiv II(15) (SSWMM-RECEIV II).

The Short Stormwater Management Model (SSWMM) and Receiv II (RECEIV II) are both modified versions of the EPA-SWMM model.(16) SSWMM, developed by the University City Science Center in 1976, is a simplified version of the runoff portion of the EPA-SWMM model, and RECEIV II, developed by the Raytheon Company and the EPA in 1974, is a modified version of the receiving water portion of the EPA-SWMM model. When combined, SSWMM and RECEIV II are capable of dynamically simulating both the quantity and quality of stormwater runoff and the impact of such runoff on the quantity and quality of receiving waters including rivers, lakes, and estuaries. The user can define, with certain restrictions, the quality parameters which he chooses to simulate. Pollutant transport can be modeled by both overland flow and sewer routing. Dry weather flows can also be simulated. The model is primarily designed to simulate individual storm events but can be used to model multiple storm periods.

Potential model application for both runoff and receiving water simulation includes all industry categories identified in this report; however, model development and modification is required for any such application. This includes modifying portions of both SSWMM and RECEIV II and interfacing SSWMM and RECEIV II.

SSWMM model simulations of the quantity of stormwater runoff are adequate for specific industrial land uses, but the quality simulations are inadequate. Presently, the quality relationship is based on finite source land utilization with all types of industry lumped into a single industrial land use category. Consequently, it was necessary to develop quality relationships and pollutant accumulation and washoff characteristics on a specific industry basis. RECEIV II modifications were necessary to enhance model definition which ensures the model's sensitivity to a specific plant's point and non-point discharges.

3.3.2 Detailed Model Description of SSWMM - RECEIV II

The SSWMM - RECEIV II model as developed in this program consists of the following four distinct programs:

SSWMM (Short Stormwater Management Model Program)
LNKPRG (Link Program)
SETUP/QUANTITY (RECEIV II Quantity Program)
QUALITY (RECEIV II Quality Program)

SSWMM simulates both the quantity and the quality of stormwater runoff. LNKPRG interfaces SSWMM and RECEIV II (SETUP/QUANTITY and QUALITY), while RECEIV II SETUP/QUANTITY simulates hydraulics in the receiving water and the impact of the stormwater runoff on these hydraulics.

RECEIV II QUALITY simulates water quality in the receiving water and the impact of the stormwater runoff on the quality of the receiving water. A complete model listing for each of the four programs is listed in Appendix B.

A descriptive flowchart for SSWMM - RECEIV II is presented in Figure 3-6. As indicated in the flowchart, SSWMM - RECEIV II must be operated in a SSWMM, LNKPRG, SETUP/QUANTITY, QUALITY sequence. SSWMM, LNKPRG, and SETUP/QUANTITY produce informational output files which serve as input to the next program in the sequence. QUALITY, the last program in the sequence, does not generate an output file. Input card decks are required for SSWMM, LNKPRG, SETUP/QUANTITY, and QUALITY. Results are printed out for SSWMM, LNKPRG, SETUP/QUANTITY, and QUALITY.

Detailed descriptions for SSWMM, LNKPRG, SETUP/QUANTITY, and QUALITY are presented below.

3.3.2.1 SSWMM (Short Stormwater Management Model Program)

The Short Stormwater Management Model Program (SSWMM) is primarily designed to simulate a storm event on a watershed, predicting both quantity and quality of storm-generated discharges. The analytical framework used to describe the watershed includes both space and time. The spatial framework consists of discrete elements that are either subcatchments (drainage areas within a watershed with overland flow) or gutters (drainage ditches, pipes, manholes, and inlets, i.e., points of runoff entry to receiving waters). The temporal framework (computational timestep length) is user selected.

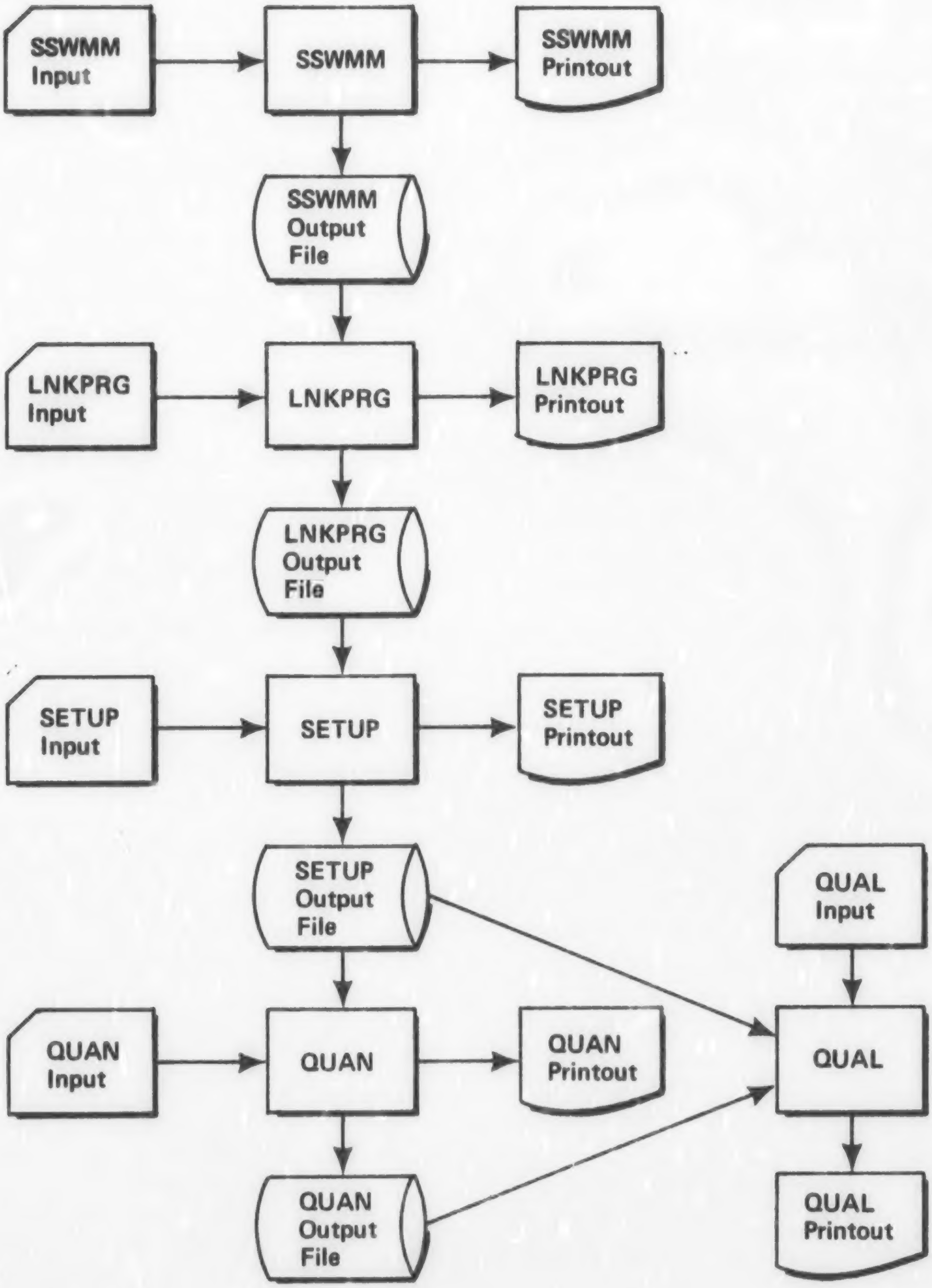

Fig. 3-6
SSWMM - RECEIV II Flowchart

SSWMM consists of a MAIN program and seven subroutines which are briefly described below. More detailed information can be found in the SSWMM Documentation.(17)

MAIN

The MAIN program in SSWMM performs three specific functions: 1) initialization, 2) control of computational loops, and 3) termination.

1) Initialization is a three step procedure which is done both within MAIN and in two of its subroutines. The first step calls for SUBROUTINE READIN, which reads all general input data and specific quantity data for each element. Next, all necessary variables and vectors must be set to zero before the storm starts. This is performed within MAIN itself. Finally, SUBROUTINE QSHEDI is called to initialize all specific quality data on each subcatchment.

2) Computation of flow and pollutant routing is performed within two major DO LOOPS: a TIMESTEP loop and an ELEMENT loop. For each timestep every element calls its specific subroutines to calculate the quantity and quality of discharges. Subcatchments call SUBROUTINE WSHED to route water off surfaces and SUBROUTINE QSHEDII to compute pollutant wash-offs. Pipes and manholes call SUBROUTINE GUTTER to simulate the flow of water through the sewer system and SUBROUTINE GQUAL to compute pollutant concentrations and mass loads.

3) If the user wishes to combine sanitary sewage flow with wet weather flow, SUBROUTINE DWF is called after stormwater routing has ended. Otherwise, the program terminates.

SUBROUTINE READIN

The first subprogram called from MAIN is SUBROUTINE READIN. Its function is to read the following five classes of input data:

1) General Information about the Simulated Basin, the Storm, and Output Options.

If the user wishes to save any quantity and quality results on file, he must specify, within this class of information, the file name and those elements he wants saved.

2) Specific Information about the Storm

This includes the length of the storm (number of rainfall intervals), and the rainfall intensity in each of these intervals.

3) Specific Quantity Parameters for Each Element

Element connectivity, areas of subcatchments, pipe lengths and diameters, flow widths and slopes are characteristics of this information.

4) General Quantity Parameters

This class of information is common to either pipes or subcatchments. Manning's coefficients, storage depths, infiltration rates, and decay coefficients are typical of this needed data. Default values from SWMM are often used for these variables.

5) General Quality Information

Unlike the EPA SWMM model, SSWMM allows much flexibility with this data. The model can simulate up to eight pollutants. Previous to the discretization methodology, one must first select eight major land uses characteristic of the entire watershed. (SWMM defaults its land uses.) Upon doing so, eight dust and dirt loading rates (estimated areas of pollutant accumulation per land use) are submitted as data. It is also necessary to choose eight pollutants that will be routed in the drainage system. The concentration of each of these in a typical catchbasin within the region is then required as input, stored in a 1 x 8 vector. The concentration of these constituents on the watershed (mg pollutant/gm of dust and dirt) is stored in an 8 x 8 matrix containing eight pollutant concentrations for each of the eight land uses selected.

SUBROUTINE QSHEDI

Prior to the storm, subroutine QSHEDI is called from MAIN for each subcatchment. Its function is to read specific quality information about each watershed and compute initial pollutant loads both on its surface and in its catchbasins.

Specific quality information, as general quality information, is also very flexible. After eight major land uses have been chosen, the percentage of each of these within each subcatchment should be estimated and verified so that they need not be changed during model Calibration/Verification (C/V). Input of the number of catchbasins within each subcatchment, the total area of each land use within each subcatchment, and a removal efficiency needed for pollutant initialization should then be included.

Pollutant initialization on the surface is a multistep procedure. The first step is to calculate the total amount of dust and dirt on the surface. Next the total concentration of each pollutant in a gram of dust and dirt is summed over all land uses within each subcatchment. These eight concentrations are then multipled by the total amount of dust and dirt on the surface to obtain the final pollutant mass load accumulation before the storm starts.

Pollutant initialization in catchbasins is computed for each constituent by multiplying the estimated amount of water in one catchbasin by the total number of catchbasins in the subcatchment times the concentration of the specific pollutant within a catchbasin.

SUBROUTINE WSHED

Subroutine WSHED is called from MAIN for each subcatchment for every timestep. Its major function is to compute flow (quantity off the surface). This flow is based on the rainfall intensity during the current timestep, and a water depth on the surface accumulated from the previous rainfall timestep.

Total flow off the watershed is summed over three flows particular to three land surfaces. They are: 1) the impervious area of the subcatchment with immediate runoff, 2) the impervious area of the subcatchment without immediate runoff, and 3) the pervious area of the subcatchment. A depth for each type of land surface is calculated using the Newton-Raphson iterative technique and a modified Manning's equation. If the depth correction function does not converge within 11 iterations, a convergence error is printed and input data must be modified. Flow for each land surface is then calculated by subtracting infiltration (if any) and the Newton-Raphson depth correction factor from the new rainfall and multiplying this result by the surface area. Total flow off the surface is computed by summing the three flows particular to the three land surfaces.

Calculation of infiltration on the pervious area of the watershed is computed by Horton's equation for every timestep for each watershed. The infiltration is accumulated as well as the total amount of rainfall and printed at the end of the stormwater routing process. Surface storage, however, is calculated only during the last timestep for each element over the pervious area of the watershed and the impervious area that retains some water. It is also printed at the end of the drainage process.

SUBROUTINE QSHEDII

Subroutine QSHEDII is called from MAIN after flows have been routed off the watershed's surface. This subprogram computes pollutant washoff from the surface and out of its catchbasins.

Computations of pollutants off the surface use an exponential decay function, as well as the amount of pollutant remaining on the surface at the end of the previous timestep and the average flow between the current and previous timesteps. The exponential decay function is based on the average flow over the area, an exponential decay coefficient, and the timestep length. Pollutants remaining on the watershed at the end of this timestep are calculated by taking the previous amount of pollutants on the surface minus the pollutants being washed off for the current timestep.

The amount of pollutants coming out of the catchbasins is calculated using an exponential decay function and the amount of pollutants remaining in the catchbasins at the end of the previous timestep. This function also uses the average flow and the total amount of water in all the catchbasins. Pollutants remaining in catchbasins at the end of the timestep are calculated the same way as pollutants remaining on the surface.

Total pollutant washoff is finally summed as pollutant washoff from the surface and pollutants flushed from the catchbasins.

SUBROUTINE GUTTER

Subroutine GUTTER is called from MAIN to route water and pollutants through sewer pipes and manholes. Unlike Subroutine WSHED, this subprogram must sum all water coming from upstream elements. These elements may be a watershed(s) and/or a gutter(s). Pipes and manholes will always have at least one upstream element but never more than three.

Similar to WSHED, GUTTER is executed for all pipes and manholes for every timestep. Its function is to produce a final depth in each element at the end of each timestep, and a flow from that element.

This subroutine also uses the Newton-Raphson numerical method and a modified Manning's equation to determine a depth correction factor. If the equation involved does not converge within thirty iterations, an error is generated and input data must be checked. To eliminate convergence errors one may add more iterations or halve the timestep size. Another possibility of error arises when too much water is allowed to flow into the pipe and the element surcharges. In this case, pipe sizes should be checked and altered, or the TRANSPORT BLOCK of SWMM should be run.

Generally speaking, total flow out of a pipe is an average flow over the entire timestep. It is calculated using the depth from the previous timestep and the modified depth from the current timestep. This flow is then emptied into the downstream pipe or manhole for further routing.

SUBROUTINE GQUAL

Subroutine GQUAL is immediately called from MAIN after stormwater has been routed in GUTTER. This subprogram produces quality results within pipes and manholes. It is similar to Subroutine GUTTER in that upstream contributions must first be added to the element. These pollutant contributions, from either subcatchments or pipes, are stored in a flux vector needed for quality computation.

Unlike the EPA Storm Water Management Model, SSWMM computes pollutant concentrations using a mass balance equation and the concept of a continuously stirred tank reactor (CSTR).

$$M_{i-1,\, j,\, o} + M_{i,\, j-1,\, r} = M_{i,\, j,\, r} + M_{i,\, j,\, o}$$

where:

i = element

j = timestep

o = out

r = remaining

This mass balance equation states that pollutants coming into an element plus the pollutants left in the element from the previous timestep must equal the pollutants going out of the element plus the pollutants remaining at the end of the current timestep. When using the concept of a CSTR, it is assumed that concentration going out and concentration remaining are equal. This enables the attainment of a mass accountability for all pollutants in all elements.

Besides producing quality results, Subroutine GQUAL also sums total gutter flow out of the last downstream element. After the system has drained, a check for unaccounted water is made and a percentage error is calculated. The unaccounted water is equal to the total rainfall minus (infiltration, gutter flow, and storage), divided by the total rainfall. Results are considered reasonable if this error is within two percent.

SUBROUTINE DWF

Unlike all the other computational subprograms, DWF makes no estimation of flow or pollutant concentrations of sanitary sewage discharges. Data with this information must be supplied by the user along with the diurnal variation, based on a 24-hour cycle. Dry weather flow is calculated by multiplying the sanitary sewage flow times the variation. This flow, calculated for each timestep, is then added to the flow calculated for each corresponding timestep under wet weather conditions. Pollutant mass loads are also calculated for each timestep by multiplying the sewage pollutant concentration times the diurnal variated flow. These mass loads are also added to the mass loads produced from wet weather conditions and printed as output.

As discussed above, SSWMM input includes information such as physical descriptions of the discretization elements, storm activity, antecedent pollution generation, and washoff data. Detailed input information requirements for SSWMM are listed in Appendix C of this report.

Output information (printout and file) is described in Tables 3-19 and 3-20. Primary output components are time-dependent, storm-generated flows and pollutant mass loads.

The utilization of SSWMM is influenced by inherent program assumptions and by modifications TRC has made. SSWMM was not designed to simulate stormwater percolation through or the erosion of material storage piles (infinite sources) but only to simulate stormwater runoff.

TABLE 3-19

SSWMM PRINTOUT

1. General input data and characteristic element data
2. All computed pollutant loads initially on each watershed and in its catchbasins for the first timestep.
3. Convergence errors on watersheds*
4. Convergence errors in pipes*
5. Surcharge in pipes*
6. Flow and mass loads for each constituent for every timestep**
7. Total rainfall, total infiltration, total runoff, total storage, and the error computed for unaccounted water.
8. Total runoff (wet weather flow and dry weather flow), total pollutant mass loads for any eight constituents computed under dry and wet weather conditions.

* NOTE: Convergence and surcharge errors must be corrected to insure correct quantity and quality results.

** NOTE: Flow and mass loads will be printed out only for those elements specified in the input vector ISAVE.

TABLE 3-20

SSWMM OUTPUT FILE

1. Title Read in

2. Number of timesteps

   Number of inlets

   Number of pollutants to be saved on file

   Timestep length (sec)

   Time storm starts (sec)

   Total area (acres)

3. Inlet numbers being saved

4. Print at end of each timestep

   Time (secs), flows (ft^3/sec) for each inlet, up to a maximum of 8 pollutant mass loads (lbs/min) for each inlet

When total settleable solids and total suspended solids are selected for modeling, they must be chosen as pollutant numbers one and two respectively, since SSWMM uses a distinct computational procedure for each of these pollutants. Other pollutants, arbitrarily chosen by the user, must be modeled as pollutant numbers three through eight. Fecal coliform cannot be modeled in the TRC modified version of SSWMM. TRC has also modified SSWMM so that the initial pollutant load buildup on the land surface is not a function of gutter length in each subcatchment but is a function of the area of each land use within each subcatchment which is more representative of industrial sites.

3.3.2.2 LNKPRG (Link Program)

The LNKPRG Program serves to interface the SSWMM and the RECEIV II (SETUP/QUANTITY, QUALITY) programs.

Specifically, LNKPRG:

1. Relates the startup time of the storm in SSWMM to the startup time for RECEIV II.
2. Establishes an ordered array correlating the position of pollutants in the SSWMM output file to the position of pollutants in the RECEIV II input array.
3. Identifies the names of the pollutants in the RECEIV II input array.
4. Converts the flow and pollutant loadings on the SSWMM output file from English to metric units (flow from CFS to m^3/sec and pollutant loadings from lbs/min to mg/sec) in conjunction with correlating the SSWMM timestep length to the RECEIV II (QUANTITY) timestep length. When the SSWMM timestep length is less than the RECEIV II (QUANTITY) timestep length, the flow and pollutant loading values on the SSWMM output file are averaged over the RECEIV II (QUANTITY) timestep. When the SSWMM timestep length is greater than or equal to the RECEIV II (QUANTITY) timestep length, the flow and pollutant values on the SSWMM output file are not changed by LNKPRG as a function of time.

5. Introduces all additional (non storm-related) point source flows and loadings, i.e., background river flows and pollutant loadings, tributary flows and pollutant loadings, river withdrawals due to river branching, and industrial withdrawals and discharges to RECEIV II.

Input information to LNKPRG includes the SSWMM output file and an input card deck. The card input consists of program interface instructions. Details are listed in Appendix C of this report.

Output from LNKPRG is provided on file and as printout. The file provides metric flow and pollutant loading information to RECEIV II (SETUP/QUANTITY, QUALITY) at the RECEIV II (QUANTITY) timestep length, while the printout lists metric flow and pollutant loadings at each of the SSWMM timesteps.

Limitations to LNKPRG include the following:

1. The RECEIV II (QUANTITY) timestep length must be a multiple of the SSWMM timestep length.
2. Additional point source flows and loadings are considered as steady state (constant as a function of time).

3.3.2.3 SETUP/QUANTITY (RECEIV II Quantity Program)

SETUP/QUANTITY processes the information from LNKPRG and computes the flow characteristics in the receiving water and the impact of the stormwater runoff on the receiving water flow characteristics. More detailed information than that presented below can be found in the RECEIV II Documentation Report.(18)

SETUP is a subroutine of QUANTITY. It creates an information file from the LNKPRG Program output file and card deck input which is used by both the RECEIV II Quantity Program and the RECEIV II Quality Program.

QUANTITY computes the temporal and spatial distribution of flow in the receiving waters. The analytical framework used to describe the waterway includes space and time. The spatial framework uses the discrete element method in which state variables such as water surface elevation are computed at nodes (junctions) and transport (flow and velocity) is computed in channels linking the nodes. The temporal framework consists of discrete, uniform timesteps selected by the user.

"The fundamental equations of the QUANTITY model are the reduced, one-dimensional form of the equation of motion for uniform, incompressible flow in the open channels between the nodes:

$$\frac{\partial v}{\partial t} = -v \frac{\partial H}{\partial X} - F_f + F_w \tag{1}$$

and the continuity equation expressing conservation of mass of an incompressible fluid in the open-topped nodes:

$$A \frac{\partial H}{\partial t} = -Q \tag{2}$$

where:

v = velocity (m/s)

t = time (s)

x = distance along the channel (m)

H = water surface elevation referenced to datum plane of the model (m)

g = gravitational acceleration ($\approx 9.8\ m/s^2$)

F_f = acceleration due to fluid resistance (m/s^2)

F_w = acceleration due to wind stress (m/s^2)

Q = the net flow out of the node (m^3/s)

A = the surface area of the node (m^2)

The acceleration due to fluid resistance is estimated by the Manning formula:

$$F_f = \frac{gn^2 v|v|}{R^{4/3}} \qquad (3)$$

where:

n = Manning's roughness factor ($s/m^{1/3}$)

R = hydraulic radius (m)

The acceleration due to wind stress is estimated by the Ekman formula:

$$F_w = \frac{K}{R} \frac{\rho_a}{\rho_w} U^2 \cos \Psi \qquad (4)$$

where:

K = windstress coefficient (~ 0.0026)

$\frac{\rho_a}{\rho_w}$ = ratio of air density to water density ($\approx 1.165 \cdot 10^{-3}$)

U = wind speed (m/s)

Ψ = angle between the wind direction and the axis of the channel." 19

Input requirements for SETUP/QUANTITY are quite extensive and include geographical, meteorological, and hydraulic information on the waterway, and flow and pollutant loading information describing discharges to and withdrawals from the waterway. This input information is provided by the LNKPRG output file and two input card decks. Specific input data for SETUP/QUANTITY is described in Appendix C of this report.

Output from SETUP/QUANTITY includes files and printout. Both SETUP and QUANTITY produce output files. The SETUP file provides QUANTITY with information from LNKPRG and as such serves as an interface. The QUANTITY file contains information on the stage or tidal height at each node, the flow in each channel, and the velocity in each channel. In addition, QUANTITY provides a computational printout which includes the same information as contained on the QUANTITY file.

Limitations to SETUP/QUANTITY result from assumptions made in the program and the modifications made to the program during this project. A fundamental limitation of the SETUP/QUANTITY program is that river channels must be represented as being rectangular. This approximation can break down under low flow conditions in a river. Another limitation inherent in the program is that the QUALITY timestep must always be greater than or equal to the QUANTITY timestep. In addition, the ratio of the user selected QUALITY to QUANTITY timestep is a function of river velocity. For instance, for velocities of 0.5 meters/sec, the ratio of the user selected QUALITY to QUANTITY timestep must be less than or equal to 12 to insure computational stability.

In addition, TRC has modified SETUP/QUANTITY by:

1. Reducing the maximum number of nodes that can be modeled from 100 to 10.
2. Reducing the maximum number of channels that can be modeled from 225 to 10.
3. Expanding the node and channel printout arrays from 30 print cycles to 250 print cycles while reducing the number of nodes or channels for which data can be printed out from 50 to 10.
4. Placing the portion of the CONTROL DATA Input Deck applicable to QUANTITY directly into the SETUP/QUANTITY program.

Modifications 1 through 3 were performed to enhance the sensitivity and applicability of SETUP/QUANTITY for specific near-field industrial applications which require small scale geographic discretization and small timestep length choices. Modification 4 was made to simplify model use.

3.3.2.4 QUALITY (RECEIV II Quality Program)

QUALITY uses the flow characteristic information from SETUP/QUANTITY to compute water quality in the receiving water and the impact of the stormwater runoff on that water quality. More detailed information than that presented below can be found in the RECEIV II Documentation.(20)

As with SETUP/QUANTITY, QUALITY uses an analytical framework of space and time to describe the waterway. The spatial framework uses the discrete element method in which state variables such as constituent concentration are computed at nodes. The temporal framework consists of discrete, uniform timesteps selected by the user.

"The fundamental form of the equations describing volumetric average water quality constituent concentration in a node is:

$$\frac{dC}{dt} = \frac{1}{V} - \frac{M}{V^2} \quad \frac{dV}{dt} \tag{5}$$

where:

C = volumetric average constituent concentration (typically, gm/m^3)

M = constituent mass in node (typically, gm)

V = volume of node (m^3)

Equation (5) expresses the concept of conservation of mass in a control volume, frequently called a continuously stirred tank reactor. The derivatives on the right can be evaluated in terms of the flows and constituent masses crossing the boundaries of the node, and in terms of the biochemical reactions taking place in the node:

$$\frac{dC}{dt} = \frac{1}{V} \Sigma Q_j \quad (C_j - C) + \Sigma Q_i \quad (C_i - C) + \Sigma M_g - \Sigma M_d \qquad (6)$$

where Q_j = flows entering node from upstream nodes (m^3/s)

Q_i = flows entering node from point and non-point sources (m^3/s)

C_j = concentration of constituent entering node from upstream nodes (typically, gm/m^3)

C_i = concentration of constituent entering node from point and non-point sources (typically, gm/m^3)

M_g = rate of constituent mass gained due to biological, physical or chemical processes in the node (typically, gm/s)

M_d = rate of constituent mass lost due to biological, physical or chemical processes in the node (typically, gm/s)

The interactions among the 11 water quality constituents modeled in RECEIV-II are presented in the ($\Sigma M_g + \Sigma M_d$) terms. For example, the rather complex interactions affecting the dissolved oxygen are formulated as:

$$\frac{1}{V} (\Sigma M_g - \Sigma M_d) = k_9 \, (C^* - C_9) - k_7 C_7 - a_{9,\,4} k_4 \, C_4 - a_{9,\,5} k_5 C_5 +$$
$$a_{9,\,8} \, (G_8 - D_8^1) \, C_8 - (b/R) \qquad (7)$$

where C_9 = nodal concentration of DO

C^* = saturation concentration of DO

k_9 = DO reaeration rate

C_7 = nodal concentration of carbonaceous BOD

k_7 = rate of oxidation of carbonaceous BOD

C_4 = nodal concentration of ammonia nitrogen

k_4 = rate of oxidation of ammonia nitrogen to nitrite nitrogen

$a_{9,4}$ = stoichiometric ratio of oxygen in nitrite

C_5 = nodal concentration of nitrite nitrogen

k_5 = rate of oxidation of nitrite nitrogen to nitrate nitrogen

$a_{9,5}$ = stoichiometric ratio of oxygen in nitrate

C_8 = nodal concentration of chlorophyll a

G_8 = "growth" rate of chlorophyll a

D_8' = adjusted "death" rate of chlorophyll a

$a_{9,8}$ = stoichiometric ratio of oxygen produced per unit "growth" of chlorophyll a

b = benthic oxygen demand

All reaction rates (k's) are adjusted for the effects of temperature during computation. Equations for computation of BOD oxidation rate, DO surface reaeration, DO reaeration at dams, saturation DO and exchange at the tidal boundaries are detailed in the RECEIV-II Documentation Report".(21)

Input requirements for QUALITY include the output files from SETUP/QUANTITY and a card deck input. The card input includes information such as initial pollutant concentrations in the receiving water and pollutant reaction kinetics (reaction rates, water temperatures, and temperature compensation coefficients). Specific card inputs for QUALITY are described in Appendix C of this report.

Output from QUALITY is in the form of printout. The primary computational outputs include pollutant concentrations at each node at the user selected timestep, and maximum, minimum, and average pollutant concentrations on a daily basis for each node.

QUALITY was modified to recognize six new constituents including sulfates (SULFATES), total iron (TOTAL FE), manganese (MANGANESE), aluminum (ALUMINUM), total dissolved solids (TDS), and total suspended solids (TSS). The new constituents were placed in the following order:

Former Constituent Name		New Constituent Name
Total Nitrogen	-	SULFATES
Phosphorous	-	TOTAL FE
Coliforms	-	MANGANESE
Ammonia		
Nitrite		
Nitrate		
Carbonaceous BOD	-	ALUMINUM
Chlorophyll A		
Dissolved Oxygen		
Salinity	-	TDS
Metal Ion	-	TSS

Reaction rates for the new constituents should be set to 0.0 in the QUALITY input card deck as these constituents are treated as non-reactive elements. As with SETUP/QUANTITY, the portion of the CONTROL DATA INPUT DECK applicable to QUALITY was placed directly into the Quality Program to simplify model use.

3.3.3 Model Application

After the model development work was completed, SSWMM-RECEIV II was used in conjunction with the field sampling program (Section 3.2) to simulate the quantity and quality of stormwater runoff and its impact on the quantity and quality of receiving waters at two coal-fired electric generating plants. As indicated in Section 3.2.2, the two plants were the Warren Generating Station on the Allegheny River in Warren, Pennsylvania and the Portland Generating Station on the Delaware River in Portland, Pennsylvania. The pollutants modeled included total suspended solids, total dissolved solids, sulfates, total iron, manganese, and aluminum. Each of these pollutants was treated as a non-reactive substance.

In total, four model runs were made; three at Warren and one at Portland. The three model runs made at the Warren Generating Station were:

1. Run 1 - An initial model run with the September 17, 1976 storm
2. Run 2 - A calibration model run with the September 17, 1976 storm
3. Run 3 - A verification model run with the August 26, 1976 storm.

Run 1 was an initial model run of the storm of September 17, 1976 with first estimates made for selected model inputs. In Run 2, new estimates for the selected model inputs for Run 1 were made so that the model results would compare more closely to field measurements during the September 17, 1976 storm. Hence, the model was calibrated. The September 17, 1976 storm was used for calibration since both stormwater flow and pollutant concentration data were available from the field measurement program; only stormwater pollutant concentration data were available from the field measurement program for the August 26, 1976 storm. In Run 3 the calibrated model was tested (without changing the new estimates made in Run 2) with a second set of storm conditions from the storm of August 26, 1976. This was a verification run.

The one model run made at the Portland Generating Station was designated as Run 4, the storm of October 20, 1976. Run 4 was intended to test the ability of the model to simulate stormwater runoff conditions at a second power plant with different operating characteristics. This represented a limited test of the model's universality or ability to be transferred to different sites in the utility industry.

Fundamental model inputs and important results for Runs 1 through 4 are discussed below in Sections 3.3.3.1 and 3.3.3.2. A complete listing of the model inputs for Runs 1 through 4 is presented in Appendix D.

3.3.3.1 Fundamental Model Inputs

Fundamental model inputs to SSWMM - RECEIV II include dividing land areas and the receiving water into discrete elements, pollutant generation activity on land, storm activity, and background flow and pollutant loadings in the receiving waters.

The discrete element scheme used as input at Warren for Runs 1, 2, and 3 is illustrated in Figures 3-7 and 3-8 and is described in Tables 3-21 and 3-22.

As depicted in Figure 3-7, the land area was divided into three watersheds based on drainage patterns and land use. These watersheds are represented by elements 1, 4, and 6. The discharge point of drainage from each of the three watersheds to the river is classified as an

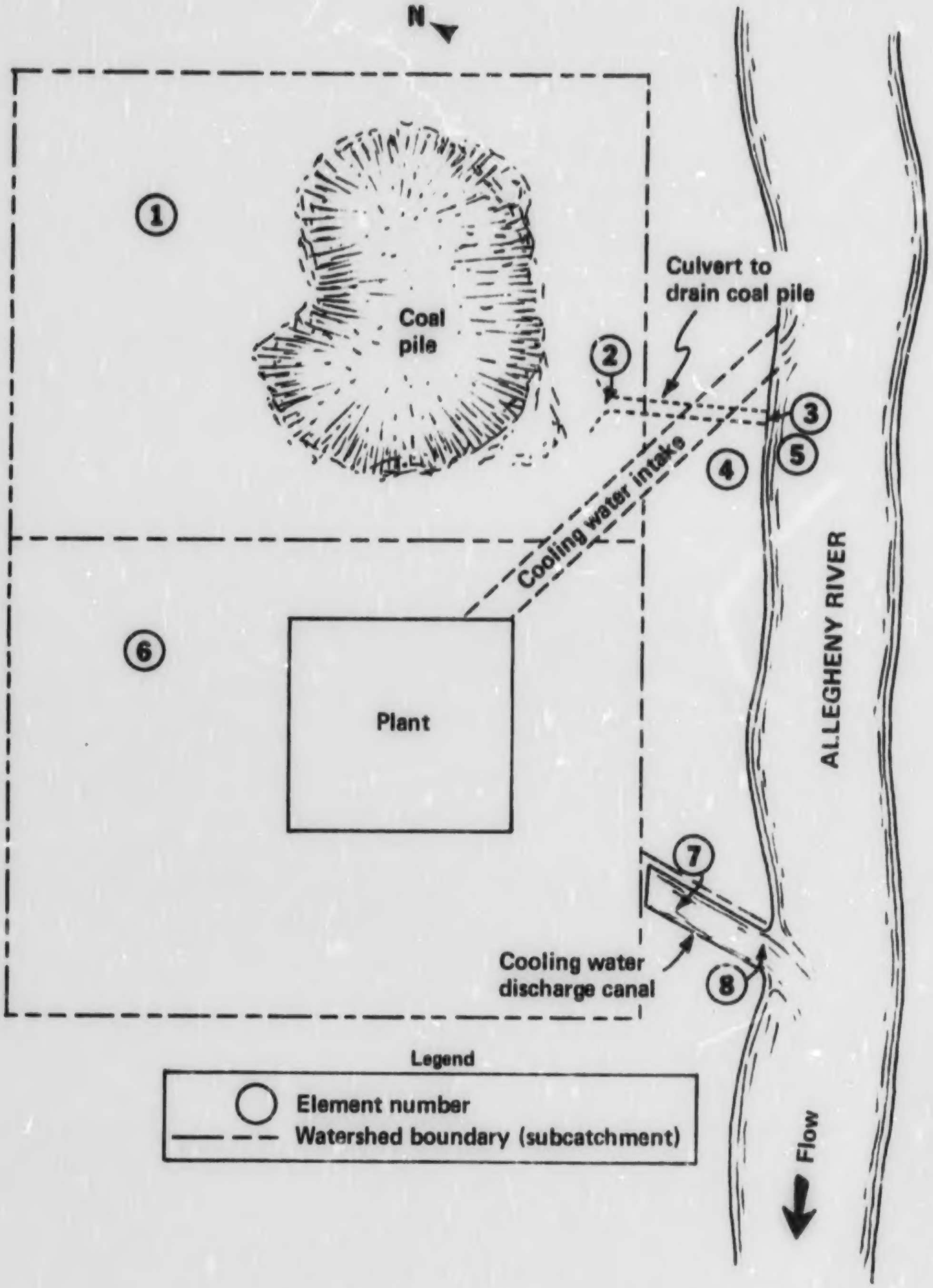
N
①
Coal pile
Culvert to drain coal pile
②
③
⑤
④
Cooling water intake
ALLEGHENY RIVER
⑥
Plant
⑦
Cooling water discharge canal
⑧
Legend
Element number
Watershed boundary (subcatchment)
Flow

Fig. 3-7
Discretization scheme schematic
of land area; Warren, PA.

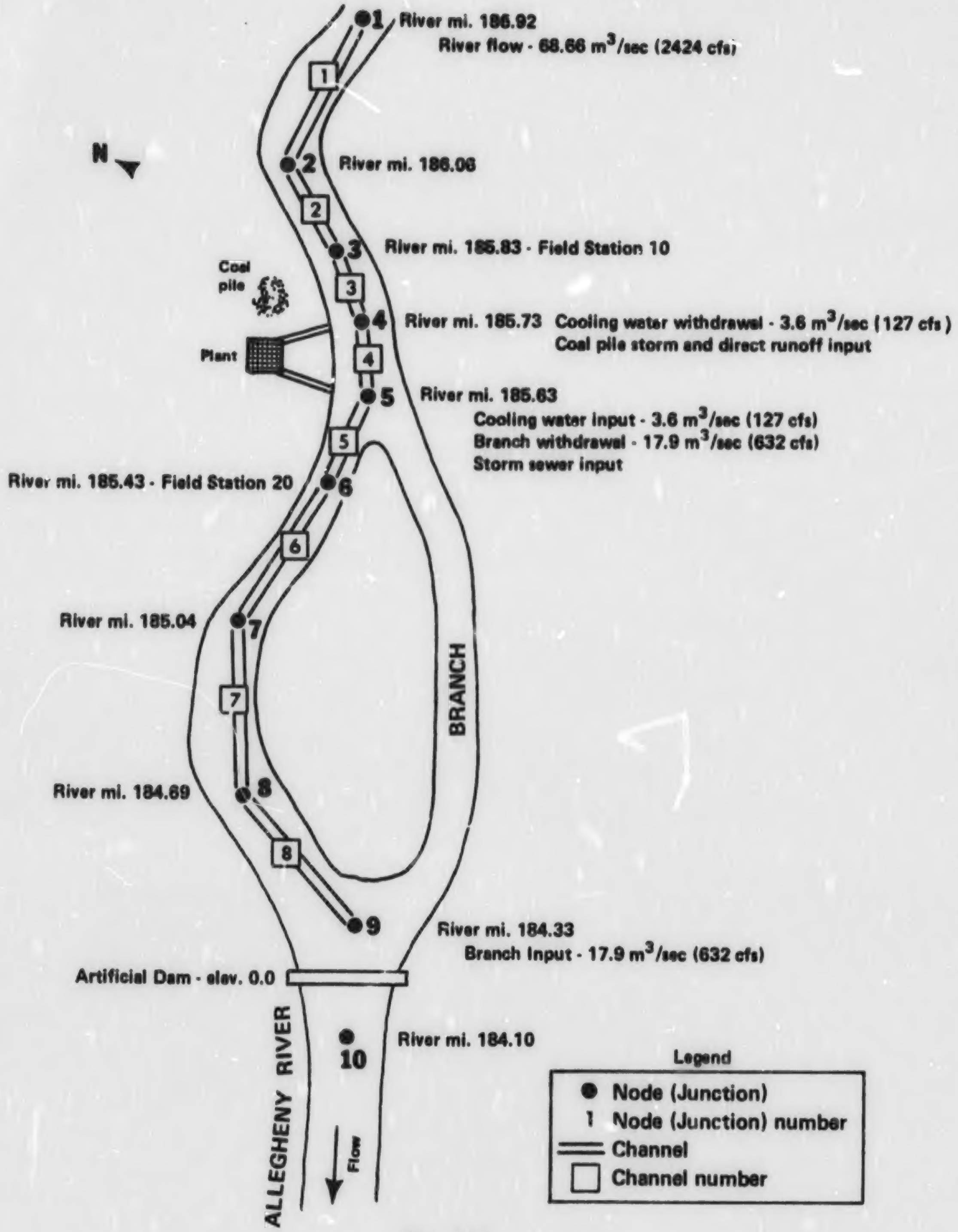
1 River mi. 186.92
River flow - 68.66 m^3/sec (2424 cfs)
N
2 River mi. 186.06
3 River mi. 185.83 - Field Station 10
Coal pile
4 River mi. 185.73 Cooling water withdrawal - 3.6 m^3/sec (127 cfs)
Coal pile storm and direct runoff input
Plant
5 River mi. 185.63
Cooling water input - 3.6 m^3/sec (127 cfs)
Branch withdrawal - 17.9 m^3/sec (632 cfs)
Storm sewer input
River mi. 185.43 - Field Station 20 6
River mi. 185.04 7
River mi. 184.69 8
9 River mi. 184.33
Branch Input - 17.9 m^3/sec (632 cfs)
BRANCH
Artificial Dam - elev. 0.0
10 River mi. 184.10
ALLEGHENY RIVER
Flow
1
2
3
4
5
6
7
8
Legend
● Node (Junction)
1 Node (Junction) number
Channel
Channel number

Fig. 3-8

Discretization scheme schematic
of Allegheny River; Warren, PA.

TABLE 3-21

DISCRETE LAND ELEMENTS
WARREN, PA

Element No.	Type[1]	Width (ft)	Slope (ft/ft)	AR OR GL[2]	PI OR DF[2]
1	1	338.00	0.0180	2.61	100.00
2	2	1.00	0.1370	153.13	0.95
3	2	0.00	0.0000	0.00	0.00
4	1	488.00	0.1370	1.71	100.00
5	2	0.00	0.0000	0.00	0.00
6	1	275.00	0.0450	2.53	100.00
7	2	25.00	0.0220	325.00	23.75
8	2	0.00	0.0000	0.00	0.00

[1] Type 1 is a watershed
Type 2 is a pipe or manhole

[2] AR = Area of watershed (Ac); PI = Percent imperviousness (%)
GL = Pipe length (Ft) ; DF = .95 * Width

TABLE 3-22

DISCRETE RIVER ELEMENTS
WARREN, PA

Nodes (Junctions)

Junction Number	Surface Area (Sq M)	Channels Entering Junction							
1	184072.00	1	0	0	0	0	0	0	0
2	111646.00	2	1	0	0	0	0	0	0
3	29350.00	3	2	0	0	0	0	0	0
4	23184.00	4	3	0	0	0	0	0	0
5	39078.00	5	4	0	0	0	0	0	0
6	68644.00	6	5	0	0	0	0	0	0
7	75948.00	7	6	0	0	0	0	0	0
8	80203.00	8	7	0	0	0	0	0	0
9	47265.00	8	0	0	0	0	0	0	0
10	47265.00	0	0	0	0	0	0	0	0

Channels

Channel Number	Length (M)	Width (M)	Manning Coefficient	Bottom Elev (M - POS DN)*	Junctions at Ends	
1	1384.	133.	0.033	-1.7	1	2
2	370.	106.	0.033	-1.6	2	3
3	161.	121.	0.033	-1.4	3	4
4	161.	167.	0.033	-1.2	4	5
5	307.	167.	0.033	-1.2	5	6
6	460.	187.	0.033	-1.2	6	7
7	383.	172.	0.033	-1.0	7	8
8	690.	137.	0.033	-0.4	8	9

* (M - POS DN): Measured positive downward from data plane.

inlet. These inlets are labeled as elements 3, 5, and 8. The first watershed (element 1) represents the coal pile drainage area. The runoff from this area enters a culvert (element 2) which empties into the Allegheny River at element 3. The second watershed (element 4) describes the drainage area between the plant, the coal pile, and the river. Runoff from this area enters the Allegheny River at element 5. The third watershed (element 6) includes the drainage area adjacent to the plant. Runoff from this drainage area enters the cooling water discharge canal (element 7) which empties into the Allegheny River at element 8. Physical dimensions for each of these elements are listed in Table 3-21.

Based on the physical characteristics of the river and the location of the stormwater runoff discharges to the river, the Allegheny River was divided into ten nodes and eight channels, as illustrated in Figure 3-8. Background river flow and pollutant loadings enter node 1. Stormwater runoff discharges from the coal pile drainage area (element 1) and the drainage area between the plant, coal pile, and the river (element 4) enter the river at node 4, and the stormwater runoff discharge from the drainage area adjacent to the plant (element 6) enters the river at node 5. Cooling water for the power plant is withdrawn at node 4 and is discharged at node 5. The river branches at node 5 and is unified at node 9. Since the model requires the last node in the discretization system to be immediately downstream from a dam, even if one does not exist, an artificial dam, i.e., a dam with no elevation above the river bottom, was placed between nodes 9 and 10. Channels connect each of the nodes except where the nodes are interrupted by the dam.

The physical characteristics for the node and channel discretization scheme are listed in Table 3-22.

The discrete element scheme used as input at Portland for Run 4 is illustrated in Figures 3-9 and 3-10 and described in Tables 3-23 and 3-24.

Based on drainage patterns and land use, the land area was divided into four watersheds labeled as elements 1, 3, 5, and 8 in Figure 3-9. The four watersheds discharge to the Delaware River at two inlet points represented as elements 2 and 11. The first watershed (element 1) represents the ash handling and ash pile drainage area. The runoff from this area enters the Delaware River overland at element 2. The second watershed (element 3) is the drainage area for the plant substation, the third watershed (element 5) is the drainage area for the coal pile runoff, and the fourth watershed (element 8) is the drainage area adjacent to the plant. Stormwater runoff from these three watersheds enters a storm sewer system described by elements 4, 6, 7, 9, and 10 which in turn discharges to the Delaware River through element 11. The physical dimensions for each of these elements are listed in Table 3-23.

Based on the physical characteristics of the Delaware River and the location of the stormwater discharges to the river, the Delaware River was divided into seven nodes and five channels, as illustrated in Figure 3-10. Background river flow and pollutant concentrations enter node 1. Stormwater runoff discharges from the ash handling and ash pile area (element 1) enter the river at node 3, and the stormwater runoff discharge from the substation (element 4), coal pile (element 5), and the plant area (element 8) enter the river at node 4. Cooling water

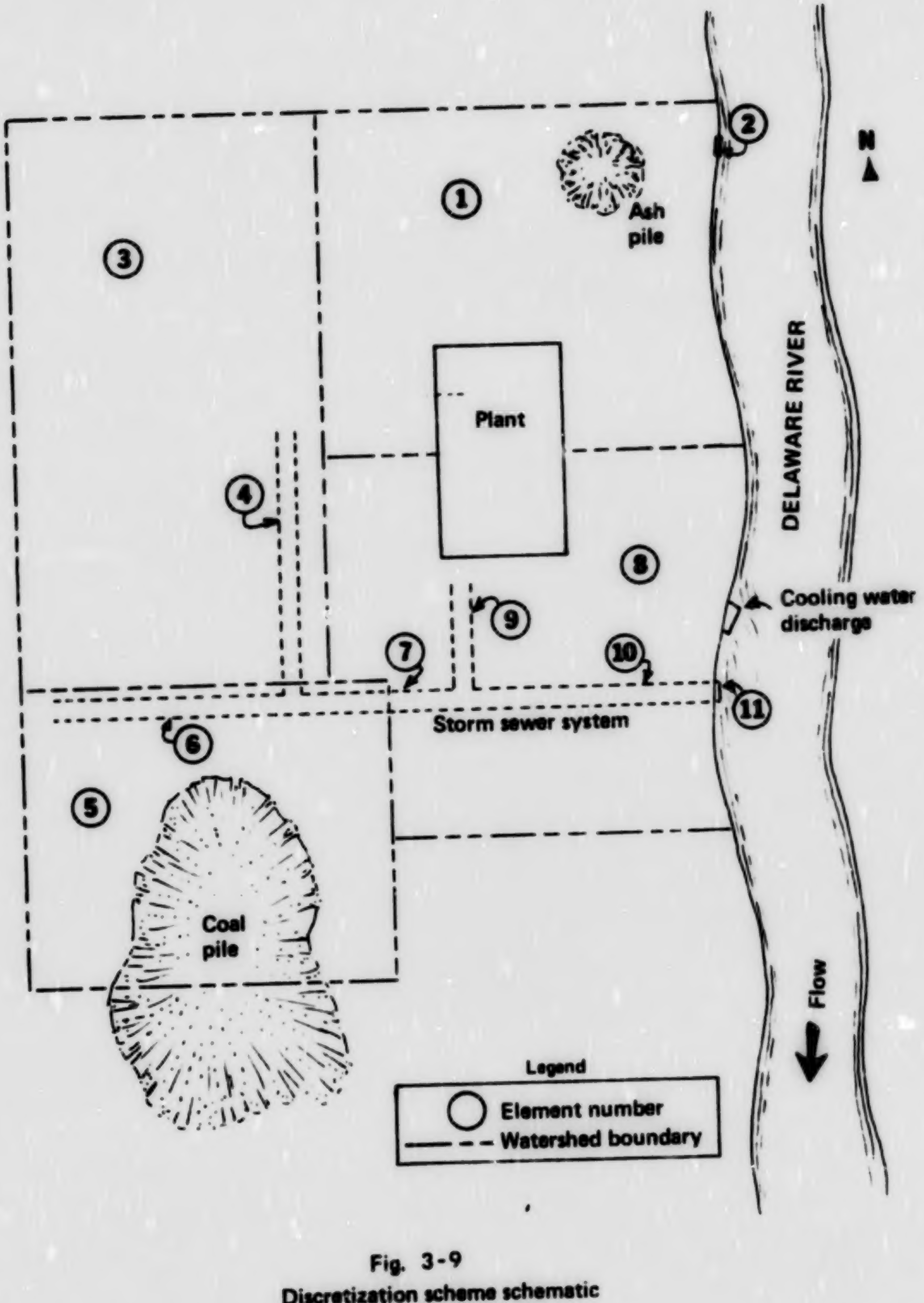

Fig. 3-9
Discretization scheme schematic
of land area; Portland, PA.

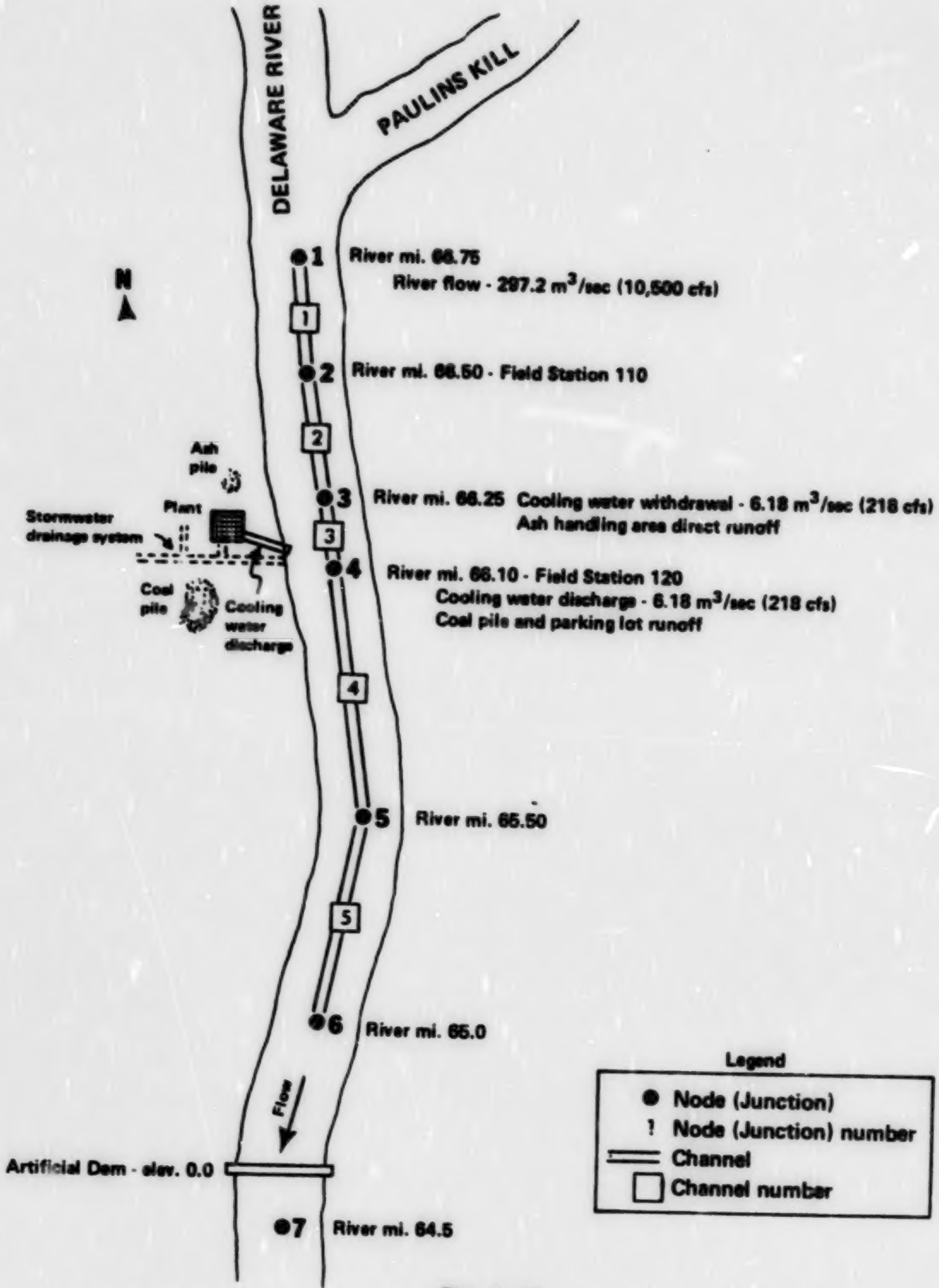
DELAWARE RIVER
PAULINS KILL
N
1 River mi. 66.75
River flow - 297.2 m³/sec (10,500 cfs)
1
2 River mi. 66.50 - Field Station 110
2
Ash pile
Plant
Stormwater drainage system
3 River mi. 66.25 Cooling water withdrawal - 6.18 m³/sec (218 cfs)
Ash handling area direct runoff
3
4 River mi. 66.10 - Field Station 120
Cooling water discharge - 6.18 m³/sec (218 cfs)
Coal pile and parking lot runoff
Coal pile
Cooling water discharge
4
5 River mi. 65.50
5
6 River mi. 65.0
Flow
Artificial Dam - elev. 0.0
7 River mi. 64.5
Legend
● Node (Junction)
1 Node (Junction) number
Channel
Channel number

Fig. 3-10
Discretization scheme schematic
of Delaware River; Portland, PA.

TABLE 3-23

DISCRETE LAND ELEMENTS
PORTLAND, PA

Element No.	Type[1]	Width (Ft)	Slope (Ft/Ft)	AR OR GL[2]	PI OR DF[2]
1	1	808.00	0.0500	13.36	50.00
2	2	0.00	0.0000	0.00	0.00
3	1	1220.00	0.0080	17.48	33.33
4	2	1.75	0.0100	817.00	1.66
5	1	698.00	0.0020	11.90	100.00
6	2	1.75	0.0169	462.00	1.66
7	2	3.00	0.0096	223.00	2.85
8	1	1320.00	0.0500	10.23	100.00
9	2	1.75	0.0100	442.00	1.66
10	2	3.00	0.0096	452.00	2.85
11	2	0.00	0.0000	0.00	0.00

[1] Type 1 is a watershed
Type 2 is a pipe or manhole

[2] AR = Area of watershed (AC); PI = Percent imperviousness (%)
GL = Pipe length (Ft) ; DF = .95 * width

TABLE 3-24

DISCRETE RIVER ELEMENTS
PORTLAND, PA

Nodes (Junctions)

Junction Number	Surface Area (Sq M)	Channels Entering Junction							
1	93861.00	1	0	0	0	0	0	0	0
2	92022.00	2	1	0	0	0	0	0	0
3	74722.00	3	2	0	0	0	0	0	0
4	130490.00	4	3	0	0	0	0	0	0
5	172638.00	5	4	0	0	0	0	0	0
6	71779.00	5	0	0	0	0	0	0	0
7	71779.00	0	0	0	0	0	0	0	0

Channels

Channel Number	Length (M)	Width (M)	Manning Coefficient	Bottom Elev (M - POS DN)*	Junctions at Ends	
1	402.	233.	0.033	-2.8	1	2
2	402.	224.	0.033	-2.7	2	3
3	241.	245.	0.033	-3.4	3	4
4	966.	209.	0.033	-3.5	4	5
5	805.	178.	0.033	-1.6	5	6

* (M - POS DN): Measured positive downward from data plane.

for the power plant is withdrawn at node 3 and is discharged at node 4. As with the Allegheny River discrete element scheme, an artificial dam, i.e., a dam with no elevation above the river bottom, was placed between nodes 6 and 7. Channels connect each of the nodes except where the nodes are interrupted by the dam. The physical characteristics for the node and channel element scheme are listed in Table 3-24.

As described in the SSWMM - RECEIV II Model Development Section of this report, the amount of pollutant washed from the land surface during a storm is, in part, related to the initial (pre-storm) mass of pollutant on the land surface. The initial pollutant mass load is equal to the dust and dirt accumulation rate multiplied by the area of the watershed with that dust and dirt accumulation rate, the number of dry days between storms, and the amount of a particular pollutant in the dust and dirt. The dust and dirt accumulation rate and the amount of a particular pollutant in the dust and dirt used as inputs for Runs 1, 2, 3, and 4 were determined from dust sampling programs for both the Warren and Portland Generating Stations. The area of the watershed with that dust and dirt accumulation rate and the number of dry days between storms were determined from discrete element schemes and meteorological records respectively.

The results of the dust and dirt sampling and analyses programs are summarized in Table 3-25. At the Warren Generating Station (Runs 1, 2, and 3), one dust and dirt accumulation rate (.003 lbs/dry day - ft^2) was representative of all the watersheds. At the Portland Station (Run 4), two dust and dirt accumulation rates were developed--one for the coal pile, plant, and substation watersheds (.0003 lbs/dry day - ft^2)

TABLE 3-25

SUMMARY RESULTS OF DUST AND DIRT SAMPLING PROGRAM AS INPUT TO MODEL

Location	Activity	Dust and Dirt Accumulating Rate (Lbs/Dry Day-Ft^2)	mg Pollutant Per Gram of Dust and Dirt					
			TSS	Sulfates	Total Fe	Manganese	Aluminum	TDS
Warren Generating Station	Entire Plant Area	.003[1]	993.5	1.0	18.7	.3	3.4	6.5
Portland	Coal Pile and Adjacent Area	.0003[2]	997.91	1.11	.016	.003	.015	2.09
	Ash Handling Area	.00055[2]	998.39	1.18	.004	.0013	.0066	1.61

[1] The dust and dirt load increased at this accumulation rate without reaching an ultimate level over a 15-day period.

[2] The dust and dirt load increased at this accumulation rate for approximately four days after which the total dust and dirt load remained at a constant level.

and one for the ash handling watershed (.00055 lbs/dry day - ft^2). The amount of pollutant in the dust and dirt also varied between the Warren and Portland Generating Stations. Total suspended solids and sulfate levels were slightly higher at Portland, while total iron, manganese, aluminum, and total dissolved solids levels were substantially lower at Portland.

Storm activity input data consisted of field measurements of rainfall intensity. The results are summarized in Table 3-26. The storm of September 17, 1976 at the Warren Generating Station was used for model Runs 1 and 2. This storm lasted approximately seven hours and was described as a steady drizzle with intermittent, short but heavy, showers. The maximum rainfall intensity was 0.11 inches/hour, and the cumulative rainfall was 0.33 inches. The storm of August 26, 1976, was used for model Run 3 at Warren. This storm was a short (20-minute) shower with a maximum rainfall intensity of 0.33 inches/hour and a cumulative rainfall of 0.11 inches. The storm used for model Run 4 at Portland occurred on October 20, 1976. The storm lasted approximately 14 hours and was described as a steady drizzle with intermittent, short but heavy showers. The maximum rainfall intensity was 0.16 inches/hour, and the cumulative rainfall was 1.55 inches.

Another input item of fundamental concern to SSWMM - RECEIV II is the choice of background flow and pollutant loadings in the receiving waters. Background conditions are those flow and pollutant loadings which are not influenced by the stormwater runoff of the particular site being studied.

TABLE 3-26

SUMMARY OF STORM ACTIVITY

Location	Date	Name	Storm Activity	Rainfall Intensity		Total Rainfall (in)	Comments
				(Time)	(in/hr)		
Warren Generating Station	8-26-76	Storm #1	Shower	1435-1455	0.33	0.11	Last Prior Storm Occurred on 8-15-76
Warren Generating Station	9-17-76	Storm #2	Steady Drizzle, Intermittent Showers-Heavy at Short Intervals	0800	0.00	0.33	
				0930	0.04		
				1050	0.05		
				1130	0.11		
				1230	0.07		
				1510	0.03		
Portland Generating Station	10-20-76	Storm #1	Steady Drizzle, Intermittent Showers-Heavy at Short Intervals	0800	0.00	1.55	Last Prior Storm Occurred on 10-13-76
				0810	0.06		
				0910	0.10		
				1010	0.05		
				1110	0.09		
				1140	0.16		
				1155	0.16		
				to 2130	0.12*		

*Average Intensity Based on Measured Value for Cumulative Rainfall in that Time Period

In the case of the Warren and Portland Generating Stations, background conditions were measured in the river upstream of the plant stormwater discharges. Background flows and pollutant loadings used as input to model Runs 1, 2, 3, and 4 were computed as a three-day average of the river field measurements at the upstream station for one day prior to the storm, the day of the storm, and one day after the storm. The background conditions were computed in this manner since a model restriction requires that the background inputs to the model remain unchanged for the model simulation period. A three-day simulation period was desired to allow computational stability and to monitor the storm-induced flows and pollutant concentrations for up to one day after the storm. A background river flow used as input to model Runs 1, 2, and 3 at Warren was 68.66 m^3/sec, while the background river flow at Portland for Run 4 was 297.2 m^3/sec. Background pollutant loadings, expressed as concentrations for model Runs 1, 2, 3, and 4 are shown in the tables presented with the model results in the following subsection.

3.3.3.2 Model Results

The model results from Runs 1, 2, 3, and 4 were compared to field data where comparable information was available and at time intervals where maximum runoff flows and pollutant loadings occurred in the model. Selected results were summarized to illustrate the nature of and the impact of stormwater runoff at the Warren and Portland Generating Stations. The results of the model and field measurement comparison are presented in Tables 3-27 through 3-31 for Model Runs 1, 2, 3, and 4.

For model Run 1, the initial model run at the Warren Generating Station, the modeled stormwater runoff flow was 0.4 of the measured flow, and the modeled stormwater runoff pollutant concentrations were within a factor of 4; i.e., the model concentration divided by the measured concentration varied between .25 and 4.0 for total suspended solids, total iron, manganese, and aluminum, but were greater than a factor of 4 for sulfates and total dissolved solids. Flow measurements were not made at the site in the Allegheny River; hence, modeled and measured river flows could not be compared. Modeled and measured pollutant concentrations in the Allegheny River compared within a factor of 3. The results for Run 1 are shown in Table 3-27.

In model Run 2, the calibration model run at the Warren Generating Station, the impervious area water retention storage depth was reduced from .062 inches in Run 1 to .001 inches in Run 2 to increase the modeled percentage of the total rainfall that was runoff. This change was made since the area was almost completely impervious The percentage of runoff, therefore, should be approximately equal to 100%, and in Run 1 it was only 86%. In Run 2 the percentage runoff was 99%. The impervious area water retention storage was maintained at .001 inches for Runs 3 and 4.

In Run 2 the modeled stormwater runoff flow and pollutant concentrations and the modeled river pollutant concentrations compared to the field measurements with approximately the same degree of accuracy as with Run 1. As with Run 1 it was not possible to compare modeled and field measured flow parameters in the Allegheny River. Run 2 results are shown in Table 3-28.

TABLE 3-27

COMPARISON OF MODEL RESULTS TO FIELD DATA
MODEL RUN 1, STORM 2, (INITIAL RUN)
WARREN GENERATING STATION

SSWMM

	Model[1] Inlet 3		Meas[1] Sta. 34	Factor Model/ Meas	Model[2] Inlet 5		Meas[2] Sta. 31 32,33	Factor Model/ Meas	Model[3] Inlet 8		Meas[3] Sta. 42	Factor Model/ Meas
Flow (CFS)	.26		.68	.4	.15		No Data	-	.12		No Data	-
Pollutant	#/min	mg/1	mg/1		#/min	mg/1	mg/1		#/min	mg/1	mg/1	
TSS	6.635	6819	4028.	1.7	3.078	3163	2058 - 5410	1.5-.6	2.434	5420	2695.	2.0
SO_4	.0325	33.4	2100.	.02	.0174	31.0	225-475.	.1-.06	.0213	5.7	3000.	.002
Tot.Fe	.607	623.8	700.	.9	.325	579	153-300	3.8-1.9	.398	886.	1025.	.9
Mn	.010	10.3	10.4	1.0	.005	8.9	3.5-6.0	2.5-1.5	.006	13.4	16.0	.8
Al	.110	113.	79.0	1.4	.059	105.1	23.5-71.	4.5-1.5	.072	160.3	111.0	1.4
TDS	.211	216.8	3135.	.07	.113	5.3	357-618	.01-.008	.138	307.3	5456.	.06

[1] Time = Model = 1130; Meas = 1110 - 1120
[2] Time = Model = 1115; Meas = 1100 - 1115
[3] Time = Model = 1030; Meas = 1020

RECEIV[7]

Quality

Pollutant	Max. Conc.[4] (mg/1)	Junction	Background (mg/1)	Measurement[5] Sta. 20 (mg/1)	Factor Model/Meas
TSS	13.536	6	11.610	4.5	3.0
SO_4	16.174	6	16.170	16.0	1.0
Tot.Fe	.355	6	.190	.74	.5
Mn	.033	6	.030	.06	.6
Al	1.030	6	1.000[6]	1.000[6]	1.0
TDS	105.228	6	105.198	99.00	1.1

[4] Time = 1200
[5] Time = 1150 - 1210
[6] 1.000 = Non-Detectable Limit.
[7] Quantity - Storm has no effect on flow characteristics.

TABLE 3-28

COMPARISON OF MODEL RESULTS TO FIELD DATA
MODEL RUN 2, STORM 2, (CALIBRATION RUN)
WARREN GENERATING STATION

SSWMM

	Model[1] Inlet 3		Meas[1] Sta. 34	Factor Model/ Meas	Model[2] Inlet 5		Meas[2] Sta. 31, 32,33	Factor Model/ Meas	Model[3] Inlet 8		Meas[3] Sta. 42	Factor Model/ Meas
Flow (CFS)	.26		.68	.4	.15		No Data	-	.13		No Data	-
Pollutant	#/min	mg/l	mg/l		#/min	mg/l	mg/l		#/min	mg/l	mg/l	
TSS	6.501	6681	4028.	1.6	3.01	5362.	2058 - 5410	2.6-1.0	2.754	5660	2695.	2.1
SO_4	.0263	27.0	2100	.01	.0141	25.1	225-475.	.1-.05	.0191	39.2	3000.	.01
Tot.Fe	.493	506.6	700	.7	.263	468.5	153-300	3.1-1.6	.358	736.	1025.	.7
Mn	.008	8.2	10.4	.8	.004	7.1	3.5-6.0	2.0-1.2	.006	12.3	16.0	.8
Al	.090	92.5	79.0	1.2	.048	85.5	23.5-71.	3.6-1.2	.065	133.6	111.0	.8
TDS	.171	175.7	3135	.06	.091	162.1	357-618	.4-.3	.124	255.	5456.	.05

[1] Time = Model = 1130; Meas = 1110 - 1120
[2] Time = Model = 1115; Meas = 1100 - 1115
[3] Time = Model = 1030; Meas = 1020

RECEIV[7]

Quality

Pollutant	Max. Conc.[4] (mg/l)	Junction	Background (mg/l)	Measurement[5] Sta. 20 (mg/l)	Factor Model/Meas
TSS	13.446	6	11.610	4.5	3.0
SO_4	16.173	6	16.170	16.0	1.0
Tot.Fe	.324	6	.190	.74	.4
Mn	.032	6	.030	.06	.5
Al	1.024	6	1.000[6]	1.000[6]	1.0
TDS	105.217	6	105.198	99.00	1.1

[4] Time = 1200
[5] Time = 1150 - 1210
[6] 1.000 = Non-Detectable Limit.
[7] Quantity - Storm has no effect on flow characteristics.

For model Run 3, the verification model run at the Warren Generating Station, the modeled stormwater pollutant concentrations also compared to the field measurements with approximately the same degree of accuracy as did Run 1. No measured stormwater flow data were available to compare to the modeled flow results. Again, it was not possible to compare modeled flow to measured flow in the Allegheny River since such measurements were not made in the river. Modeled and measured pollutant concentrations in the Allegheny River compared within a factor of 4. The results for Run 3 are shown in Table 3-29.

For model Run 4, the initial model run at the Portland Generating Station, it was not possible to compare modeled and measured stormwater runoff flow since no field data were available on stormwater flow. Modeled stormwater pollutant concentrations were different from field measurements by greater than a factor of 4. As with the Warren site, it was not possible to compare modeled and measured river flows since river flow was not measured at the site. Modeled and measured pollutant concentrations in the Delaware River compared within a factor of 5. Results for Run 4 are shown in Tables 3-30 and 3-31.

The model was not calibrated at Portland because stormwater flow field measurements were not available, and it is first necessary to calibrate flow in the model before any other model adjustments are warranted.

Selected model results illustrating the nature of and the impact of stormwater runoff from model Runs 1, 2, 3, and 4 at the Warren and Portland Generating Stations are listed in Tables 3-32, 3-33, 3-34, and 3-35.

TABLE 3-29

COMPARISON OF MODEL RESULTS TO FIELD DATA
MODEL RUN 3, STORM 1, (VERIFICATION)
WARREN GENERATING STATION

SSWMM

	Model[1] Inlet 3		Meas[1] Sta. 34	Factor Model/ Meas	Model[2] Inlet 5		Meas[2] Sta. 31 32,33	Factor Model/ Meas	Model[3] Inlet 8		Meas[3] Sta. 42	Factor Model/ Meas
Flow (CFS)			No Data		.21		No Data	-			No Data	
Pollutant	#/min	mg/l	mg/l		#/min	mg/l	mg/l		#/min	mg/l	mg/l	
TSS			No Data		1.939	2467.	1027 - 2965.	2.4-.83			No Data	
SO_4					.0143	18.2	1750 - 10510.	.01-.002				
Tot.Fe					.267	340.	108-700	3.1-.48				
Mn					.004	5.1	9.6-45.	.53-.1				
Al					.049	62.3	42.5-334	1.5-.2				
TDS					.093	118.	2405 - 8107.	.05-.01				

[1] Time = No Data During Storm
[2] Time = 1445
[3] Time = No Data During Storm.

RECEIV[7]

Quality

Pollutant	Max. Conc.[4] (mg/l)	Junction	Background (mg/l)	Measurement[5] Sta. 20 (mg/l)	Factor Model/Meas
TSS	7.839	6	7.73	No Data	-
SO_4	12.481	6	12.48	No Data	-
Tot.Fe	.249	6	.23	.06	4.2
Mn	.030	6	.030	.013	2.3
Al	1.003	6	1.000[6]	1.000[6]	1.0
TDS	114.502	6	114.5	No Data	-

[4] Time = 1600
[5] Time = 1550 - 1650
[6] 1.000 = Non-Detectable limit.
[7] Quantity - Storm has no effect on flow characteristics.

TABLE 3-30

COMPARISON OF MODEL RESULTS TO FIELD DATA
MODEL RUN 4, STORM 1,
PORTLAND GENERATING STATION

SSWMM

	Model[1] Inlet 2		Measure[1] Station 131, 132	Factor Model/ Measure	Model[2] Inlet 11		Meas[2] Sta. 134B	Factor Model/ Meas
Flow (CFS)	.83		No Data	-	2.34		No Data	-
Pollutant	#/min	mg/l	mg/l		#/min	mg/l	mg/l	
TSS	.543	175.	2344-10932	.07-.02	1.015	116.	280.	.4
SO_4	.0037	1.2	1200-1600	.001-.0008	.0058	.7	400.	.002
Tot.Fe	<.001	<.32	73-245	.004-.001	<.001	<.1	385.	.0002
Mn	<.001	<.32	.03-2.5	10.-.13	<.001	<.1	1.75	.06
Al	<.001	<.32	125-138	.002-.002	<.001	<.1	50.	.002
TDS	.005	1.6	1843-2504	.0008-.0006	.011	1.2	698.	.002

[1] Time = 1115
[2] Time = 1045

RECEIV[3]

Quality

Pollutant	Max. Conc.[4] (mg/l)	Junction	Background (mg/l)	Measurement[5] Sta. 120 (mg/l)	Factor Model/Meas
TSS	16.070	4	15.999	7.1	2.3
SO_4	14.611	4	14.618	9.0	1.6
Tot.Fe	.570	4	.570	.45	1.3
Mn	.050	4	.050	.01	5.0
Al	1.000	4	1.000[6]	1.000[6]	1.0
TDS	67.455	4	67.486	45.7	1.5

[3] Quantity - Storm has little effect on flow characteristics in river (Less than .05% increase in river flow at max. storm discharge).

[4] Time = 1200
[5] Time = 1130 - 1200 and 1230 - 1300
[6] 1.000 = Non-Detectable Limit.

TABLE 3-31

COMPARISON OF MODEL RESULTS TO FIELD DATA
MODEL RUN 4, STORM 1,
PORTLAND GENERATING STATION

SSWMM	Model[1] Inlet 2		Measure[1] Station 131, 132	Factor Model/ Measure	Model[2] Inlet 11		Meas[2] Sta. 134B	Factor Model/ Meas
Flow (CFS)	.81		No Data	-	3.38		No Data	-
Pollutant	#/min	mg/l	mg/l		#/min	mg/l	mg/l	
TSS	.590	195	13124-15213	.01-.01	1.60	126.	516.	.25
SO_4	.0018	.6	1100-1300	.0005-.0004	.0027	.213	1200.	.0002
Tot. Fe	<.001	<.3	148-300	.002-.001	<.001	<.08	280.	.0003
Mn	<.001	<.3	.04-.25	7.5-1.2	<.001	<.08	1.60	.05
Al	<.001	<.3	100-200	.003-.0015	<.001	<.08	31.3	.002
TDS	.002	.6	1631-2015	.0004-.0003	.005	.4	No Data	-

[1] Time = 1415

[2] Time = Model = 1345; Meas = 1340

TABLE 3-32

SELECTED RESULTS FROM MODEL RUNS
RUN 1, STORM 2 (INITIAL RUN)
WARREN GENERATING STATION

LOCATION*	SSWMM							RECEIV (COMBINED EFFECT OF ALL INLETS)				
	MAXIMUM FLOW RATE (cfs)	TOTAL RUNOFF cu ft	PERCENT OF RAINFALL THAT IS RUNOFF (%)	POLLUTANT LOAD ON LAND SURFACE PRIOR TO STORM (LBS)	MAXIMUM STORM WASHOFF RATE (LBS/MIN)	TOTAL STORM POLLUTANT WASHOFF (LBS)	PERCENT WASHOFF (%)	MAXIMUM POLLUTANT CONCENTRATION IN RIVER (MG/L)	LOCATION OF MAX. RIVER CONC. (JUNCTION NO)	CONCENTRATION PRIOR TO STORM (BACKGROUND) (MG/L)	CHANGE IN CONCENTRATION DUE TO STORM (MAX CONC - BACKGROUND CONC) MG/L	CHANGE IN CONCENTRATION DUE TO STORM (MAX CONC - BACKGROUND CONC) % CHANGE
INLET 3												
Flow	.26	7514 For inlets 3,5,8	86 For inlets 3,5,8					Flow not changed by storm				
TSS				7350.2	8.037	1031.8	14	13.89	5	11.61	2.28	+20.0
Sulfates				7.4	.0332	5.5	75	16.17	ALL	16.17	0.0	0.0
Total Fe				138.3	.621	103.4	75	.366	5	.190	.176	+93.0
Manganese				2.2	.010	1.7	75	.033	5	.030	.003	+10.0
Aluminum				25.2	.113	18.8	75	1.032	5	1.000	.032	+ 3.0
TDS				48.1	.216	36.0	75	105.2	ALL	105.2	0.0	0.0
INLET 5												
Flow	.20											
TSS				4815.6	5.835	691.0	14					
Sulfates				4.8	.0234	3.6	75					
Total Fe				90.6	.438	67.8	75					
Manganese				1.4	.007	1.1	75					
Aluminum				16.5	.080	12.3	75					
TDS				31.5	.152	23.6	75					
INLET 8												
Flow	.26											
TSS				7124.9	8.012	1006.6	14					
Sulfates				7.2	.0330	5.4	75					
Total Fe				134.1	.616	100.3	75					
Manganese				2.2	.010	1.6	75					
Aluminum				24.4	.112	18.2	75					
TDS				46.6	.214	34.9	75					

*Inlet 3 drains coal pile area.
Inlet 5 drains area between the plant and the river (direct runoff area).
Inlet 8 drains area adjacent to plant.

TABLE 3-33

SELECTED RESULTS FROM MODEL RUNS
RUN 2, STORM 2 (CALIBRATION RUN)
WARREN GENERATING STATION

	SSWMM							RECEIV (COMBINED EFFECT OF ALL INLETS)				
LOCATION*	MAXIMUM FLOW RATE (cfs)	TOTAL RUNOFF cu ft	PERCENT OF RAINFALL THAT IS RUNOFF (%)	POLLUTANT LOAD ON LAND SURFACE PRIOR TO STORM (LBS)	MAXIMUM STORM WASHOFF RATE (LBS/MIN)	TOTAL STORM POLLUTANT WASHOFF (LBS)	PERCENT WASHOFF (%)	MAXIMUM POLLUTANT CONCENTRATION IN RIVER (MG/L)	LOCATION OF MAX. RIVER CONC. (JUNCTION NO)	CONCENTRATION PRIOR TO STORM (BACKGROUND) (MG/L)	CHANGE IN CONCENTRATION DUE TO STORM (MAX CONC - BACKGROUND CONC) MG/L	CHANGE IN CONCENTRATION DUE TO STORM (MAX CONC - BACKGROUND CONC) % CHANGE
INLET 3												
Flow	.26	8652 For inlets 3,5,8	99 For inlets 3, 5, 8						Flow not changed by storm			
TSS				7350.2	7.8[illegible]	1173.0	16	13.84	5	11.61	2.23	+19.0
Sulfates				7.4	.0269	5.9	80	16.17	ALL	16.17	0.0	0.0
Total Fe				138.3	.503	110.1	80	.333	5	.190	.143	+75.0
Manganese				2.2	.008	1.8	80	.032	5	.030	.002	+ 7.0
Aluminum				25.2	.091	20.0	80	1.026	5	1.000	.026	+ 3.0
TDS				48.1	.175	38.3	80	105.2	ALL	105.2	0.0	0.0
INLET 5												
Flow	.20											
TSS				4815.6	5.706	782.3	16					
Sulfates				4.8	.0190	3.8	80					
Total Fe				90.6	355	72.1	80					
Manganese				1.4	.006	1.2	80					
Aluminum				16.5	.065	13.1	80					
TDS				31.5	.123	25.1	80					
INLET 8												
Flow	.26											
TSS				7124.9	7.834	1142.2	16					
Sulfates				7.2	.0267	5.7	80					
Total Fe				134.1	.499	106.5	80					
Manganese				2.2	.008	1.7	80					
Aluminum				24.4	.091	19.4	80					
TDS				46.6	.174	37.0	80					

*Inlet 3 drains coal pile area.
Inlet 5 drains area between the plant and the river (direct runoff area)
Inlet 8 drains area adjacent to plant.

TABLE 3-34

SELECTED RESULTS FROM MODEL RUNS
RUN 3, STORM 1 (CALIBRATION)
WARREN GENERATING STATION

	SSWMM							RECEIV (COMBINED EFFECT OF ALL INLETS)				
LOCATION*	MAXIMUM FLOW RATE (cfs)	TOTAL RUNOFF cu ft	PERCENT OF RAINFALL THAT IS RUNOFF (%)	POLLUTANT LOAD ON LAND SURFACE PRIOR TO STORM (LBS)	MAXIMUM STORM WASHOFF RATE (LBS/MIN)	TOTAL STORM POLLUTANT WASHOFF (LBS)	PERCENT WASHOFF (%)	MAXIMUM POLLUTANT CONCENTRATION IN RIVER (MG/L)	LOCATION OF MAX. RIVER CONC. (JUNCTION NO)	CONCENTRATION PRIOR TO STORM (BACKGROUND) (MG/L)	CHANGE IN CONCENTRATION DUE TO STORM (MAX CONC - BACKGROUND CONC) MG/L	% CHANGE
INLET 3												
Flow	.26	1225. For Inlets 3,5,8	92 For inlets 3, 5, 8					Flow not changed by storm				
TSS				3925.3	4.765	100.6	3	9.32	5	7.73	1.59	+20.0
Sulfates				4.0	.0276	.8	20	12.48	ALL	12.48	0.0	0.0
Total Fe				73.9	.517	14.5	20	.383	5	.230	.153	+66.0
Manganese				1.2	.008	.2	20	.032	5	.030	.002	+ 7.0
Aluminum				13.4	.094	2.6	20	1.028	5	1.000	.028	+ 3.0
TDS				25.7	.180	5.0	20	114.5	ALL	114.5	0.0	0.0
INLET 5												
Flow	.27											
TSS				2572.0	7.048	107.8	3					
Sulfates				2.6	.0277	.5	20					
Total Fe				48.4	.517	10.1	20					
Manganese				.8	.008	.2	20					
Aluminum				8.8	.094	1.8	20					
TDS				16.8	.180	3.5	20					
INLET 8												
Flow	.28											
TSS				3805.0	5.214	107.9	3					
Sulfates				3.8	.0290	.8	20					
Total Fe				71.6	.542	14.2	20					
Manganese				1.1	.009	.2	20					
Aluminum				13.0	.099	2.6	20					
TDS				24.9	.188	5.0	20					

*Inlet 3 drains coal pile area
Inlet 5 drains area between the plant and the river (direct runoff area).
Inlet 8 drains area adjacent to plant.

TABLE 3-35

SELECTED RESULTS FROM MODEL RUNS**
RUN 4, STORM 1
PORTLAND GENERATING STATION

	SSWMM							RECEIV (COMBINED EFFECT OF ALL INLETS)				
LOCATION*	MAXIMUM FLOW RATE (cfs)	TOTAL RUNOFF cu ft	PERCENT OF RAINFALL THAT IS RUNOFF (%)	POLLUTANT LOAD ON LAND SURFACE PRIOR TO STORM (LBS)	MAXIMUM STORM WASHOFF RATE (LBS/MIN)	TOTAL STORM POLLUTANT WASHOFF (LBS)	PERCENT WASHOFF (%)	MAXIMUM POLLUTANT CONCENTRATION IN RIVER (MG/L)	LOCATION OF MAX. RIVER CONC. (JUNCTION NO)	CONCENTRATION PRIOR TO STORM (BACKGROUND) (MG/L)	CHANGE IN CONCENTRATION DUE TO STORM (MAX CONC - BACKGROUND CONC) MG/L	CHANGE IN CONCENTRATION DUE TO STORM (MAX CONC - BACKGROUND CONC) % CHANGE
INLET 2												
Flow	1.07	189820 For Inlets 2, 11	65 For inlets 2, 11					Less than .05% change in river flow due to storm				
TSS				1277.1	.911	418.0	33	16.07	4,5,6	16.00	+ .07	+ .4
Sulfates				1.5	.0046	1.46	~ 100	14.61	4,5,6	14.62	- .01	- .07
Total Fe				.005	< .001	.005	~ 100	.570	ALL	.570	0.0	0.0
Manganese				.002	< .001	.002	~ 100	.050	ALL	.050	0.0	0.0
Aluminum				.008	< .001	.008	~ 100	1.000	ALL	1.000	0.0	0.0
TDS				2.0	.006	1.99	~ 100	67.45	4,5,6	67.49	- .04	- .06
INLET 11												
Flow	3.94											
TSS				2064.3	2.356	983.7	48					
Sulfates				2.3	.0071	2.19	~ 100					
Total Fe				.03	< .001	.03	~ 100					
Manganese				.006	< .001	.006	~ 100					
Aluminum				.03	< .001	.03	~ 100					
TDS				4.3	.013	4.13	~ 100					

*Inlet 2 drains ash pile and ash handling area. Inlet 11 drains coal pile and area adjacent to plant.
**Results are questionable as there were insufficient data to calibrate model at Portland.

In model Run 1, the initial model run at Warren, the total stormwater runoff was 7514 ft^3 which was 86% of the total rainfall. This runoff did not change flow conditions in the Allegheny River. Based on the components of the accumulated dust and dirt, only 14% of the pre-storm mass of total suspended solids was washed from the land surface during the storm. However, 75% of the pre-storm mass of sulfates, total iron, manganese, aluminum, and total dissolved solids was washed from the surface. Model Run 1 showed maximum pollutant concentrations increased in the river by 20% for suspended solids, by 93% for total iron, by 10% for manganese and by 3% for aluminum. These values are within the confidence limits of the means except for iron. The model shows a definite increase in iron for the second storm. The field data, however, does not show a significant increase in iron concentration. This difference is probably due to either a poor field sample or poor sample timing (i.e., the peak concentration was missed). Concentrations of sulfates and total dissolved solids remained unchanged as a result of the stormwater runoff. Selected results for Run 1 are shown in Table 3-32.

In model Run 2, the calibrated model run at Warren, the total stormwater runoff was 8,652 ft^3 which was 99% of the total rainfall. Flow characteristics in the Allegheny River remained unchanged. Sixteen percent of the pre-storm mass of total suspended solids and 80% of the prestorm mass of sulfates, total iron, manganese, aluminum, and total dissolved solids were washed from the land surface during the storm, and maximum pollutant concentrations increased in the river for total suspended solids by 19%, total iron by 75%, manganese by 7%, and aluminum by 3%. Concentrations of sulfates and total dissolved solids remained unchanged as a result of the stormwater runoff. Selected Run 2 results are shown in Table 3-33.

For Run 3, the storm of August 26, 1976 at Warren, the total stormwater runoff was 1,225 ft^3, which was 92% of the total rainfall. Flow characteristics in the Allegheny River were not changed by this storm flow. Three percent of the pre-storm mass of total suspended solids and 20% of the pre-storm mass of sulfates, total iron, manganese, aluminum, and total dissolved solids were washed from the land surface during the storm, and maximum pollutant concentrations increased in the river for total suspended solids by 20%, total iron by 66%, manganese by 7%, and aluminum by 3%. Concentrations of sulfates and total dissolved solids remained unchanged as a result of the stormwater runoff. Selected results for Run 3 are shown in Table 3-34.

In Run 4, the storm of October 20, 1976 at Portland, the total stormwater runoff was 189,820 ft^3, which was 65% of the total rainfall. Flow in the Delaware River increased by less than 0.05% as a result of the stormwater runoff. Thirty-three percent of the pre-storm mass of total suspended solids and approximately 100% of the pre-storm mass of sulfates, total iron, manganese, aluminum, and total dissolved solids were washed from the land surface during the storm. The concentrations of total suspended solids, sulfates, total iron, manganese, aluminum, and total dissolved solids in the Delaware River were not changed by the stormwater runoff. The results of model Run 4, however, are questionable as there were insufficient field data to calibrate the model at the Portland Generating Station and as the field data that did exist did not compare favorably to the modeled results. The results of Run 4 are listed in Table 3-35.

3.3.4 Results of the Model Development Program

From the work completed in this study, it appears that SSWMM - RECEIV II is capable of predicting the quantity and quality of stormwater runoff and its impact on receiving waters for specific industries, but that model limitations do exist. These limitations include the lack of capability to simulate storm erosion of infinite sources, i.e., material storage piles, and to simulate stormwater percolation through material storage piles.

SSWMM - RECEIV II is a versatile stormwater and receiving water model suited for industrial application. It is inherently flexible so that it is applicable to each of the industries identified in Section 3.1.1 of this report, with only minor data input modifications.

Specific utility industry application described in this study has demonstrated that, for the most part, where adequate field data were available, SSWMM - RECEIV II results compared favorably to field measurements. At the Warren Generating Station calibrated model results for stormwater runoff flow and pollutant concentrations (total suspended solids, total iron, manganese, and aluminum) compared within a factor of 4 and river pollutant concentrations for all six pollutants within a factor of 3 to field measurements. Most importantly. the model-field measurement comparative factor of 4 was maintained for a second storm at Warren, indicating that the calibrated model could predict the effects of different storm conditions with the same degree of accuracy established in model calibration. In essence, the model was verified, increasing model credibility and indicating the feasibility of its use for industrial applications.

Several difficulties were encountered in this model study. Modeled stormwater runoff concentrations of total dissolved solids and sulfates at the Warren Generating Station were different from the field-measured values by greater than a factor of 4. Adequate field data were not available to ascertain the comparative validity of the model at the Portland Generating Station for either stormwater runoff or the receiving water.

Although difficulties were encountered, SSWMM - RECEIV II was demonstrated to be a valid stormwater runoff and receiving water model suited to industrial application. Additional work is needed to increase model credibility and usefulness, and recommendations to that end were presented in Section 2.0.

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APPENDIX A

STATISTICAL EVALUATION OF FIELD DATA

A-1 Warren
A-2 Portland
A-3 Summary of 60% to 95% Confidence Levels

TABLE A-1

STATISTICAL EVALUATION
WARREN DATA

Case	No. of Data Elements	Arith Mean, $\bar{x}$ mg/l	Std Dev S	Coef. of Var. $\frac{S}{\bar{x}}$	Variance S^2
DRY, DOWNSTREAM					
TSS	15	4.13	3.69	0.89	13.56
SO_4	18	13.83	2.92	0.21	8.50
Fe	19	0.21	0.18	0.86	0.034
Mn	19	0.023	0.011	0.46	0.0001
Alk	24	39.33	2.10	0.05	4.41
DRY, UPSTREAM					
TSS	37	8.11	6.77	0.83	45.77
SO_4	28	13.89	2.17	0.16	4.69
Fe	35	0.23	0.067	0.28	0.004
Mn	34	0.028	0.014	0.50	0.0002
Alk	43	41.65	2.76	0.07	7.61
WET, DOWNSTREAM					
TSS	8	5.50	3.24	0.59	10.50
SO_4	10	16.65	3.15	0.19	9.89
Fe	9	0.39	0.35	0.91	0.123
Mn	8	0.043	0.014	0.327	0.0002
Alk	10	40.30	0.48	0.01	0.23
WET, UPSTREAM					
TSS	10	7.25	4.44	0.61	19.74
SO_4	11	15.09	1.39	0.09	1.94
Fe	10	0.12	0.04	0.29	0.0013
Mn	12	0.032	0.004	0.138	0.00002
Alk	9	40.33	1.22	0.03	1.50

TABLE A-2

STATISTICAL EVALUATION
PORTLAND DATA

Case	No. of Data Elements	Arith Mean, $\bar{x}$ mg/l	Std Dev S	Coef. of Var. $\frac{S}{\bar{x}}$	Variance S^2
DRY, DOWNSTREAM					
TSS	16	11.66	13.07	1.12	170.8
SO_4	20	10.10	2.34	0.23	5.48
Fe	21	0.56	0.40	0.72	0.16
Mn	21	0.055	0.045	0.81	0.002
Alk	17	15.59	2.45	0.16	6.00
DRY, UPSTREAM					
TSS	13	12.72	8.04	0.63	64.64
SO_4	17	12.86	2.54	0.198	6.47
Fe	18	0.56	0.44	0.79	0.194
Mn	17	0.051	0.035	0.68	0.001
Alk	14	16.07	3.15	0.196	9.92
WET, UPSTREAM					
TSS	5	13.54	4.76	0.35	22.64
SO_4	5	14.25	4.93	0.35	24.34
Fe	6	0.30	0.11	0.36	0.01
Mn[1]	6	0.020	0.011	0.56	0.0001
Alk	5	17.6	1.14	0.06	1.30
WET, DOWNSTREAM					
TSS	8	7.39	2.64	0.36	6.95
SO_4	13	8.15	2.17	0.27	4.72
Fe	12	0.43	0.34	0.79	0.11
Mn	12	0.016	0.010	0.64	0.0001
Alk	8	16.38	0.52	0.03	0.27

[1] One non-detected value: 0.009
Two non-detected values: 0.0045, 0.009

NOTE: None detected data were replaced with a linear progression of values between 0 and this limit of detection for each pollutant
Al = 0.2 mg/l, Mn = 0.009 mg/l, Fe = 0.05 mg/l

TABLE A-3

SUMMARY OF STATISTICAL EVALUATION (T - TEST) OF WARREN AND PORTLAND DATA AT 60% AND 95% CONFIDENCE LEVELS

	DD-UD		DD-DW		UD-UW		UW-DW	
Warren	60%	95%	60%	95%	60%	95%	60%	95%
TSS	Yes	No	Yes	No	No	No	Yes	No
SO_4	No	No	Yes	No	Yes	No	Yes	No
Fe	No	No	Yes	No	Yes	Yes	Yes	No
Mn	Yes	No	Yes	Marg	Yes	No	Yes	No
Alk	Yes	No	Yes	No	Yes	No	No	No

Portland

TSS	No	No	Yes	No	No	No	Yes	No
SO_4	Yes	No	Yes	No	Yes	No	Yes	No
Fe	No	No	Yes	No	No	No	No	No
Mn	No	No	Yes	No	Yes	No	No	No
Alk	No	No	Yes	No	Yes	No	Yes	No

Key

DD = Downstream, Dry
DW = Downstream, Wet
UW = Upstream, Wet
UD = Upstream, Dry
MARG = Marginal

Hypothesis: The means of sample sets A ($\bar{X}_A$) and B ($\bar{X}_B$) are different within confidence limits of 60% and 95%.

APPENDIX B

SSWMM - RECEIV II PROGRAM LISTING

```
* * * *
      PROGRAM SSWMM
      COMMON /TIT/ TITLE(20)
      COMMON /GENRL/ TIME,TIME2,DELT,TZERO,AREA(99),NOS,NSTEP,TAREA,DELT
     12,MQUAL
      COMMON /DIRT/ PSHED(99,8),PBASIN(99,8)
      COMMON /DDATA/ XFACT(8,8),DXFACT(8),CBFACT(8),DRYDAY
      COMMON /QSH12/ FPSX,TOTDD(99),F1(8),F2(8),CBVOL,BASINS(99),FLWLST(
     199),ISS
      COMMON /WSHD/ NHISTO,W5,W6,DECAY,WLMIN,WLMAX,WSTORE(3),SUMR,SUMI,
     1SUMST
      COMMON /GUWSG/ EFLOW(99),EWIDTH(99),SLOPE(99),DEPTH(99,3),PCIMP(99
     1),NRG(99)
      COMMON /GUGQL/ NUP(99),IUP(99,3),NCHAR(99),G6,SUMOFF
      COMMON /QUAL/ TLOAD(20,8)
      COMMON /GQLWS/ PCTZER,RAIN(4,100),ISAVE(50),NSAVE,NELT,JOUT
      COMMON /TFILE/ INLETS,ISFI(20),FLSV(20),PSAVE(20,8)
      DIMENSION C(99,8),DFULL(99),GLEN(99),QIN(99),V(99),POFF(99,8),QSUR
     1(99)
      EQUIVALENCE (PSHED(1),C(1)),(TOTDD(1),QIN(1)),(BASINS(1),V(1))
      EQUIVALENCE (PCIMP(1),DFULL(1)),(PBASIN(1),POFF(1))
      EQUIVALENCE (AREA(1),GLEN(1)),(FLWLST(1),QSUR(1))
      CALL READIN
C     INITIALIZES MATRICES AND NECESSARY VARIABLES TO ZERO
      DO 45 KT=1,NELT
      EFLOW(KT)=0.0
      QSUR(KT)=0.0
      DO 40 J=1,3
   40 DEPTH(KT,J)=0.0
   45 CONTINUE
      DO 70 LL=1,NELT
      DO 60 MM=1,NOS
      PSHED(LL,MM)=0.0
   60 PBASIN(LL,MM)=0.0
   70 CONTINUE
      SUMI=0.0
      SUMR=0.0
      SUMOFF=0.0
      SUMST=0.0
      I=1
      IF(MQUAL) 500,501,500
  500 CALL QSHED1
  501 DO 440 II=1,NSTEP
      I=I+1
      TIME=TIME+DELT
      TIME2=TIME-DELT2
      WRITE(6,1001) TITLE,TIME
 1001 FORMAT(1H1///,10X,20A4,///9X,'SUMMARY OF QUANTITY AND QUALITY RESU
     1LTS FOR TIME', F10.0/ 8X, 'QUANTITY - FLOW IN CU FT/SEC'/
     2        8X, 'QUALITY - POLLUTANT LOADINGS IN LB/MIN; COLIFORMS',  TRC CHNG
     3           ' (IF MODELED) IN MPN/MIN'//                             TRC  NEW
     2      10X, 'ELEMENT', 5X, 'FLOW', 19X, 'TSS', 6X, 'SULFATES',       TRC  NEW
     3        4X, 'TOTAL FE', 4X, 'MANGANESE', 4X, 'ALUMINUM', 7X, 'TDS'TRC  NEW
     4        //)                                                          TRC  NEW
      CALL WSHED(II)                                                      TRC  NEW
      IF(MQUAL) 350,420,350                                               TRC  NEW
```

```
* * * *
  350 CALL GSHED2(II)
  420 CALL GUTTER(II)
      CALL GQUAL(II)
  440 CONTINUE
C     SET IDWF=0 IF DRY WEATHER FLOW IS NOT TO BE MODELED
      READ(5,100) IDWF
      IF(IDWF.EQ.0) GO TO 450
      CALL DRYWF
  450 CONTINUE
  100 FORMAT(I2)
      STOP
      END
```

```
* * * *
      SUBROUTINE QSHED1
      COMMON /DIRT/ PSHED(99,8),PBASIN(99,8)
      COMMON /DDATA/ XFACT(8,8),DXFACT(8),CBFACT(8),DRYDAY
      COMMON /QSH12/ FPSX,TOTDD(99),F1(8),F2(8),CBVOL,BASINS(99),FLWLST(
     199),ISS
      COMMON /GUGQL/ NUP(99),IUP(99,3),NCHAR(99),G6,SUMOFF
      COMMON /GQLWS/ PCTZER,RAIN(4,100),ISAVE(50),NSAVE,NELT,JOUT
      DIMENSION XLAND(8),GQLEN(8),ZZZ(99,19)
C     THIS SUBROUTINE INITIALIZES ALL POLLUTANT LOADINGS
      DO 10 KT=1,NELT
      IF(NCHAR(KT)-1) 10,9,10
    9 DD=0.0
C     READ SPECIFIC QUALITY DATA
      READ(5,100) BASINS(KT),REFF,CLFREQ
  100 FORMAT(15X,4F10.0)
C     XLAND(I) CAN BE DESIGNATED AS ANY 8 ARBITRARILY CHOSEN LAND USES.
C     DUST AND DIRT LOADING RATES AND POLLUTANT CONCENTRATIONS WITHIN A
C     GRAM OF DUST AND DIRT FOR THESE LAND USES, HOWEVER, MUST BE
C     POSITIONED IN THE RIGHT LOCATION OF THE NEEDED VECTORS.
                   (E.G. DXFACT,XFACT)
      READ(5,102) (XLAND(I),I=1,8)
      READ (5,102) (GQLEN(I),I=1,8)
  102 FORMAT (8F10.5)
      ZZZ(KT,1)=BASINS(KT)
      ZZZ(KT,2)=REFF
      ZZZ(KT,3)=CLFREQ
      DO 199 KZ=1,8
      KA=KZ+3
      KB=KZ+11
      ZZZ(KT,KA)=XLAND(KZ)
  199 ZZZ(KT,KB)=GQLEN(KZ)
      DRY=DRYDAY
      IF(DRYDAY.LT.CLFREQ) GO TO 130
      TGS=1.0
      NCLEAN=DRYDAY/CLFREQ
      DO 200 J=1,NCLEAN
  200 TGS=TGS+(1.0-REFF)**J
      DRY=CLFREQ*TGS
C     THE FOLLOWING DO LOOP COMPUTES A WEIGHTED DUST AND DIRT LOADING
C     RATE AVERAGE BASED ON % LAND USE AND THE PARTICULAR DUST AND DIRT
C     LOADING RATE FOR EACH LAND USE
  130 DO 210 I=1,8
  210 DD=DD+DXFACT(I)*XLAND(I)*GQLEN(I)
C     CALCULATE THE NUMBER OF GRAMS OF DUST AND DIRT ON THE WATERSHED
C     453.6 IS A CONVERSION FACTOR (GRAMS/LB)
      DD=DD*DRY*453.6
      DO 220 K=1,8
C     THE FOLLOWING DO LOOP COMPUTES A POLLUTANT CONCENTRATION
C     (MG POLL./G DUST AND DIRT) FOR EACH POLLUTANT BASED ON A WEIGHTED
C     AVERAGE OVER ALL LAND USES
      DO 230 L=1,8
  230 PSHED(KT,K)=PSHED(KT,K)+XFACT(L,K)*XLAND(L)
C     CALCULATE THE TOTAL AMOUNT OF EACH POLLUTANT (MG) ON THE WATERSHED
      PSHED(KT,K)=PSHED(KT,K)*DD
C     CALCULATE THE TOTAL AMOUNT OF EACH POLLUTANT (MG) IN THE
```

```
* * * *
C     CATCHBASINS
  220 PBASIN(KT,K)=CBVOL*BASINS(KT)*CEFACT(K)*28.3
      TOTDD(KT)=PSHED(KT,2)
      WRITE(6,101) KT,DD,(PSHED(KT,K),K=1,8),(PBASIN(KT,K),K=1,8)
   10 CONTINUE
      WRITE(6,105)
  105 FORMAT (1H1,'  SUB',5X,'CBASINS',5X,'REFF',5X,'CLFREQ',39X,'LAND U
     1SE'/48X,'1',8X,'2',9X,'3',9X,'4',9X,'5',9X,'6',9X,'7',9X,'8'/)     TRC CHNG
      DO 502 I3=1,NELT
      IF(NCHAR(I3).EQ.2) GO TO 502
      WRITE(6,106) I3,(ZZZ(I3,I2),I2=1,19)
  502 CONTINUE
  106 FORMAT(/,13(3X,I2,F11.1,F10.2,F10.1,4X,8F10.2/40X,8F10.2/))
  101 FORMAT(//,5X,'ON WATERSHED',1X,I2,1X,'THERE ARE ',1PE10.4,1X,'GRAM
     1S OF DUST AND DIRT.',//,15X,'THE MG CONTENT OF EACH CONSTITUENT ON
     2THIS WATERSHED IS',/,15X,8(1PE10.4,2X),//,15X,'THE MG CONTENT OF E
     3ACH CONSTITUENT IN THE CATCHBASINS FOR THIS WATERSHED IS ',/,15X,8
     4(1PE10.4,2X))
      RETURN
      END
```

```
* * * *
      SUBROUTINE READIN
      COMMON /TIT/ TITLE(20)
      COMMON /GENRL/ TIME,TIME2,DELT,TZERO,AREA(99),NWS,NSTEP,TAREA,DELT
     12,MQUAL
      COMMON /DIRT/ PSHED(99,8),PBASIN(99,8)
      COMMON /DDATA/ XFACT(8,8),DXFACT(8),CBFACT(8),DRYDAY
      COMMON /QSH12/ FPSX,TOTDD(99),F1(8),F2(8),CBVOL,BASINS(99),FLWLST(
     199),ISS
      COMMON /WSHD/ NHISTO,W5,W6,DECAY,WLMIN,WLMAX,WSTORE(3),SUMR,SUMI,
     1SUMST
      COMMON /GUWSG/ EFLOW(99),EWIDTH(99),SLOPE(99),DEPTH(99,3),PCIMP(99
     1),NRG(99)
      COMMON /GUGOL/ NUP(99),IUP(99,3),NCHAR(99),G6,SUMOFF
      COMMON /GOLWS/ PCTZER,RAIN(4,100),ISAVE(50),NSAVE,NELT,JOUT
      COMMON /IFILE/ INLETS,ISFI(20),FLSV(20),PSAVE(20,8)
      DIMENSION C(99,8),DFULL(99),GLEN(99),QIN(99),V(99)
      EQUIVALENCE (PSHED(1),C(1)),(TOTDD(1),QIN(1))
      EQUIVALENCE (PCIMP(1),DFULL(1)),(BASINS(1),V(1))
      EQUIVALENCE (AREA(1),GLEN(1))
C     THIS SUBROUTINE READS AND INITIALIZES ALL GENERAL DATA NECESSARY
C     FOR THE REMAINING PARTS OF THIS PROGRAM
      READ (5,100) JOUT
      READ (5,1005) TITLE
      IF (JOUT.NE.0) WRITE (JOUT) TITLE
C     NSAVE IS EQUAL TO THE NUMBER OF ELEMENTS WHOSE FLOWS AND
C     CONCENTRATIONS ARE TO BE PRINTED
C     ISAVE(I) ARE THE NAMES OF THESE ELEMENTS
C     THE LAST ELEMENT'S OUTPUT DATA WILL ALWAYS BE PRINTED AND NEED NOT
C     BE INCLUDED AS ONE OF THE VALUES FOR ISAVE(I)
      READ(5,110) IDBAS,NSTEP,NHR,NMM,DELT,PCTZER,NSAVE,INLETS,NPFI
      READ(5,115) (ISAVE(K),K=1,NSAVE)
      READ(5,115) (ISFI(I),I=1,INLETS)
      WRITE(6,1010) TITLE,IDBAS,NSTEP,DELT
      TZERO=3600.*FLOAT(NHR)+60.*FLOAT(NMM)
      TIME=TZERO
C     NELT IS EQUAL TO THE NUMBER OF ELEMENTS (WATERSHEDS,PIPES AND THE
C     LAST MANHOLE)
      READ(5,120) NHISTO,NELT,NHYT
      IF(NHYT.EQ.0) NHYT=1
      WRITE(6,1020) NHISTO
      DO 10 IR=1,NHYT
      WRITE(6,1021) IR
      READ(5,130) (RAIN(IR,I),I=1,NHISTO)
      WRITE(6,1030) (RAIN(IR,I),I=1,NHISTO)
      DO 9 I=1,NHISTO
    9 RAIN(IR,I)=RAIN(IR,I)/43200.
   10 CONTINUE
  120 FORMAT(5I5)
 1021 FORMAT(////5X,'RAINFALL FOR HYETOGRAPH',1X,I2, ' INCHES/HOUR')    TRC CHNG
      DELT2=DELT/2.
      TAREA=0.0
      WRITE(6,1040)
      WRITE (6,1041)                                                    TRC  NEW
      WRITE(6,1045)
C     READ CHARACTERISTIC DATA PARTICULAR TO EACH ELEMENT
```

```
* * * *
      DO 20 KT=1,NELT
      READ(5,140) IELT,NCHAR(KT),NUP(KT),(IUP(KT,NN),NN=1,3),NRG(KT)
      IF(NRG(KT).EQ.1.AND.NCHAR(KT).EQ.1) NRG(KT)=1
      IF(NCHAR(KT).EQ.2) GO TO 15
      READ (5,150) EWIDTH(KT),AREA(KT),PCIMP(KT),SLOPE(KT)
      WRITE(6,1050) IELT,NCHAR(KT),NUP(KT),(IUP(KT,NN),NN=1,3),NRG(KT),E
     4WIDTH(KT),SLOPE(KT),AREA(KT),PCIMP(KT)
      TAREA=TAREA+AREA(KT)
C     CONVERT AREA TO SQUARE FEET
      AREA(KT)=AREA(KT)*43560.
      GO TO 20
   15 READ(5,155) EWIDTH(KT),GLEN(KT),SLOPE(KT)
      DFULL(KT)=0.95*EWIDTH(KT)
      WRITE(6,1050) IELT,NCHAR(KT),NUP(KT),(IUP(KT,NN),NN=1,3),NRG(KT),E
     4WIDTH(KT),SLOPE(KT),AREA(KT),PCIMP(KT)
   20 CONTINUE
      IF(JOUT.NE.0) WRITE(JOUT) NSTEP,INLETS,NPFI,DELT,TZERO,TAREA
      IF(JOUT.NE.0) WRITE(JOUT) (ISFI(I),I=1,INLETS)
C     POLLUTANT IDENTIFICATION IN WRITE STATEMENT 1055 WAS CHOSEN TO BE
C     EXACTLY LIKE SWMM. HOWEVER, THE USER MAY WISH TO IDENTIFY THESE
C     POLLUTANTS DIFFERENTLY, AS LONG AS QUALITY INPUT DATA FOR THESE
C     POLLUTANTS IS READ IN THE RIGHT LOCATION OF THE NEEDED VECTORS
C               (E.G. CBFACT,XFACT)
C     READ DEFAULT VALUES FOUND IN SWMM FOR MANNING'S COEFFICIENTS,
C     STORAGE FACTORS,MINIMUM AND MAXIMUM INFILTRATION RATES,AND DECAY
C     COEFFICIENTS
      READ(5,160) G6,W5,W6,WSTORE(1),WSTORE(2),WLMAX,WLMIN,DECAY,FPSX
      WRITE(6,165) G6,W5,W6,WSTORE(1),WSTORE(2),WLMAX,WLMIN,DECAY,FPSX
C     CONVERT THREE STORAGE VALUES TO FEET
      READ(5,161) MQUAL
  161 FORMAT(5X,I5)
      WSTORE(1)=WSTORE(1)/12.
      WSTORE(2)=WSTORE(2)/12.
      WSTORE(3)=0.0
C     CONVERT INFILTRATION RATES TO FEET/SECOND
      WLMAX=WLMAX/43200.
      WLMIN=WLMIN/43200.
C     READ GENERAL QUALITY DATA
      IF(MQUAL.EQ.0) GO TO 31
      READ(5,170) CBVOL,NQS,ISS,DRYDAY
      WRITE(6,175) CBVOL,NQS,ISS,DRYDAY
      READ(5,185) (CBFACT(I),I=1,NQS)
      WRITE(6,190) (CBFACT(I),I=1,NQS)
      READ(5,185) (DXFACT(I),I=1,8)
      WRITE(6,190) (DXFACT(I),I=1,8)
      DO 30 M=1,8
      READ(5,180) (XFACT(M,J),J=1,NQS)
   30 WRITE(6,190) (XFACT(M,J),J=1,NQS)
      READ(5,185) (F1(L),L=1,NQS)
      WRITE(6,190) (F1(L),L=1,NQS)
      READ(5,185) (F2(L),L=1,NQS)
      WRITE(6,190) (F2(L),L=1,NQS)
   31 CONTINUE
      WRITE(6,1055)
 1055 FORMAT(1H1,5X,'POLLUTANT CONCENTRATIONS AND INITIAL MASS LOADS ARE
```

* * * *

```
     1PRINTED OUT FOR 6 CONSTITUENTS.',/,5X,'THESE CONSTITUENTS, IN ORDETRC CHNG
     2R, ARE.....'/ 20X, '2-----TOTAL SUSPENDED SOLIDS'/
     3              20X, '3-----SULFATES'/  20X, '4-----TOTAL IRON'/    TRC  NEW
     4              20X, '5-----MANGANESE'/ 20X, '6-----ALUMINUM'/      TRC  NEW
     5              20X, '7-----TOTAL DISSOLVED SOLIDS')               TRC  NEW
  100 FORMAT(I2)                                                        TRC  NEW
 1005 FORMAT(20A4)
  110 FORMAT (4I2,2F5.0,3I2)
  115 FORMAT(40I2)
 1010 FORMAT(1H1,///,10X,20A4,//,10X,20A4,/////,2X,'BASIN NUMBER',I2,//,
     12X,'NUMBER OF TIME STEPS',2X,I2//12X,'TIME STEP LENGTH IN SECONDS'
     2,2X,F5.0)
 1020 FORMAT(1H0,5X,'FOR THIS STORM THERE ARE',I5,2X,'RAINFALL STEPS')
  130 FORMAT (10F5.0)
 1030 FORMAT (///,5X,10F10.2)
 1040 FORMAT(1H1,//,1X,'ELEMENT NO',6X,'TYPE',7X,'NO USE',5X,'1 USE',5X,
     1'2 USE',5X,'3 USE',5X,'HYETO',3X,'WIDTH',5X,'SLOPE  AR OR GL  PI O
     2R DF')
 1041 FORMAT (76X, '(FT)', 4X, '(FT/FT)')
 1045 FORMAT (// 2X, 'TYPE 1 IS A WATERSHED', 10X,                    TRC  NEW
     1              '(AR = AREA OF WATERSHED (AC); PI = PERCENT',      TRC  NEW
     2              ' IMPERVIOUSNESS (%))'/                            TRC  NEW
     3          2X, 'TYPE 2 IS A PIPE OR MANHOLE', 4X,                 TRC  NEW
     4              '(GL = PIPE LENGTH (FT)      ; DF = .95 * WIDTH)') TRC  NEW
  140 FORMAT(7I5)                                                      TRC  NEW
  150 FORMAT (15X,10F5.0)
  155 FORMAT(20X,3F8.0)
 1050 FORMAT(//,1X,2I10,1X,5I10,F10.2,F10.4,2F10.2)
  160 FORMAT(10F8.0)
  165 FORMAT(1H1//10F10.5)
  170 FORMAT(F10.0,2I5,F10.0)
  175 FORMAT(//F10.2,2I10,F10.2)
  180 FORMAT (8F10.0)
  185 FORMAT(8F10.0)                                                   TRC CHNG
  190 FORMAT(//8E10.3)
      RETURN
      END
```

* * * *

```
      SUBROUTINE GQUAL(II)
      REAL ML
      COMMON /GENRL/ TIME,TIME2,DELT,TZERO,AREA(99),NOS,NSTEP,TAREA,DELT
     12,NQUAL
      COMMON /GUGQL/ NUP(99),IUP(99,3),NCHAR(99),G6,SUMOFF
      COMMON /QSH12/ FPSX,TOTDD(99),F1(8),F2(8),CBVOL,BASINS(99),FLWLST(
     199),ISS
      COMMON /WSHD/ NHISTO,W5,W6,DECAY,WLMIN,WLMAX,WSTORE(3),SUMR,SUMI,
     1SUMST
      COMMON /GUWSG/ EFLOW(99),EWIDTH(99),SLOPE(99),DEPTH(99,3),PCIMP(99
     1),NRG(99)
      COMMON /GQLWS/ PCTZER,RAIN(4,100),ISAVE(50),NSAVE,NELT,JOUT
      COMMON /DIRT/ PSHED(99,8),PBASIN(99,8)
      COMMON /TFILE/ INLETS,ISFI(20),FLSV(20),PSAVE(20,8)
      COMMON /QUAL/ TLOAD(20,8)
      DIMENSION C(99,8),DFULL(99),GLEN(99),QIN(99),V(99),QSUR(99),POFF(9
     19,8)
      EQUIVALENCE (PSHED(1),C(1)),(TOTDD(1),QIN(1)),(BASINS(1),V(1))
      EQUIVALENCE (PBASIN(1),POFF(1)),(FLWLST(1),QSUR(1))
      EQUIVALENCE (PCIMP(1),DFULL(1))
      EQUIVALENCE (AREA(1),GLEN(1))
      DIMENSION FLUX(8),ML(8)
C     THIS SUBROUTINE CALCULATES POLLUTANT MASS LOADS AND POLLUTANT
C     CONCENTRATIONS IN ALL PIPES AND THE LAST MANHOLE
      DO 420 KT=1,NELT
      IF(NCHAR(KT)-2) 420,9,420
    9 IF(EFLOW(KT).GT..005) GO TO 150
      DO 130 K=1,NOS
  130 C(KT,K)=0.0
      GO TO 295
  150 DO 200 K=1,NOS
  200 FLUX(K)=0.0
      NU=NUP(KT)
      DO 240 JJ=1,NU
      K=IUP(KT,JJ)
      IF(NCHAR(K).EQ.1) GO TO 230
C     ADD UPSTREAM PIPE CONCENTRATIONS TO FLUX
      DO 220 M=1,NOS
  220 FLUX(M)=FLUX(M)+C(K,M)*EFLOW(K)
      GO TO 240
C     ADD UPSTREAM POLLUTANT WASHOFFS FROM WATERSHED TO FLUX
  230 DO 235 M=1,NOS
  235 FLUX(M)=FLUX(M)+POFF(KT,M)/28.317
  240 CONTINUE
      DO 170 MN=1,INLETS
      IF(KT.NE.ISFI(MN)) GO TO 170
      DO 174 K=1,NOS
  174 C(KT,K)=FLUX(K)/EFLOW(KT)
      GO TO 295
  170 CONTINUE
C     COMPUTE POLLUTANT CONCENTRATIONS FOR PIPES AND MANHOLE
      DO 290 K=1,NOS
  290 C(KT,K)=(FLUX(K)*DELT+(V(KT)-(QIN(KT)-EFLOW(KT))*DELT+QSUR(KT))*C(
     1KT,K))/(EFLOW(KT)*DELT+V(KT))
      IF(QSUR(KT).GT.0.) WRITE(6,9000) KT,QSUR(KT),EFLOW(KT)
```

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* * * *
 9000 FORMAT (//,' **** GUTTER',I3,' SURCHARGED, SURCHARGE=',F10.0,' CU
     1FT, FLOW = ',F5.1,' CFS'/)
  295 DO 300 N=1,NSAVE
      IF (KT.EQ.ISAVE(N)) GO TO 301
  300 CONTINUE
      GO TO 70
  301 DO 304 I=1,NQS
  304 ML(I)=C(KT,I)*EFLOW(KT)*.00374
C     ML(3)=C(KT,3)*1698.                                               TRC CHNG
      WRITE(6,1000) KT,EFLOW(KT),(ML(I),I=1,NQS)
   70 DO 112 MN=1,INLETS
      IF(KT.NE.ISFI(MN)) GO TO 112
      DO 65 I=1,NQS
   65 TLOAD(MN,I)=TLOAD(MN,I)+ML(I)*DELT/60.
      MM=NUP(KT)
      DO 298 I=1,MM
      MP=IUP(KT,I)
C     SUM ALL FLOWS FROM THE LAST PIPE ELEMENT
  298 SUMOFF=SUMOFF+EFLOW(MP)*DELT
C     CALCULATE ONLY 3 POLLUTANT MASS LOADS THAT MAY BE SAVED FOR
C     STORAGE ON FILE
      DO 1 IPL=1,NQS
    1 PSAVE(MN,IPL)=ML(IPL)
      FLSV(MN)=EFLOW(KT)
      GO TO 420
  112 CONTINUE
  420 CONTINUE
      IF(JOUT.NE.0) WRITE(JOUT) TIME,(FLSV(MN),MN=1,INLETS),((PSAVE(MN,I
     1PL),IPL=1,NQS),MN=1,INLETS)
      IF (II.NE.NSTEP) GO TO 111
C     COMPUTE PERCENTAGE ERROR FOR UNACCOUNTED WATER
      ERROR=(SUMR-SUMI-SUMOFF-SUMST)*100./SUMR
      WRITE(6,2000) SUMR,SUMI,SUMOFF,SUMST,ERROR
      WRITE(6,3000)
      DO 75 I=1,INLETS
   75 WRITE(6,3005) ISFI(I),(TLOAD(I,IT),IT=1,NQS)
C1000 FORMAT(12X,I2,5X,F7.2,1X,F10.3,2X,F10.3,4X,E10.4,5(2X,F10.3)/)
 1000 FORMAT(12X,I2,5X,F7.2,1X,F10.3,2X,F10.3,4X,F10.4,5(2X,F10.3)/)    TRC CHNG
 2000 FORMAT(1H1,///2X,'TOTAL RAINFALL (CU FT)',5X,E12.6,//,2X,'TOTAL IN
     1FILTRATION (CU FT)',5X,E12.6,//,2X,'TOTAL GUTTER FLOW (CU FT)',5X,
     2E12.6,//,2X,'TOTAL SURFACE STORAGE (CU FT)',5X,E12.6,//,2X,'ERROR
     3INCONTINUITY',5X,F10.5)
 3000 FORMAT(/////15X,'THE TOTAL POLLUTANT LOADS FOR EACH INLET ARE AS F
     1OLLOWS:'/ 15X, 'POLLUTANT LOADS IN LB; COLIFORMS (IF MODELED) IN',TRC CHNG
     2                   ' MPN'/// 10X, 'ELEMENT', 19X, 'TSS', 6X,          TRC  NEW
     3                   'SULFATES', 4X, 'TOTAL FE', 4X, 'MANGANESE', 5X,   TRC  NEW
     4                   'ALUMINUM', 7X, 'TDS'//)                           TRC  NEW
C3005 FORMAT(12X,I2,2X,2(2X,F10.3),4X,E10.4,5(2X,F10.3)//)
 3005 FORMAT(12X,I2,2X,2(2X,F10.3),4X,F10.4,5(2X,F10.3)//)              TRC CHNG
  111 CONTINUE
      RETURN
      END
```

```
* * * *
      SUBROUTINE QSHED2(II)
      COMMON /GENRL/ TIME,TIME2,DELT,TZERO,AREA(99),NQS,NSTEP,TAREA,DELT
     12,MQUAL
      COMMON /DIRT/ PSHED(99,8),PBASIN(99,8)
      COMMON /QSH12/ FPSX,TOTDD(99),F1(8),F2(8),CBVOL,BASINS(99),FLWLST(
     199),ISS
      COMMON /GUWSG/ EFLOW(99),EWIDTH(99),SLOPE(99),DEPTH(99,3),PCIMP(99
     1),NRG(99)
      COMMON /GUGQL/ NUP(99),IUP(99,3),NCHAR(99),G6,SUMOFF
      COMMON /GQLWS/ PCTZER,RAIN(4,100),ISAVE(50),NSAVE,NELT,JOUT
      DIMENSION PML(3),POFF(99,8)
      EQUIVALENCE (PBASIN(1),POFF(1))
C     THIS SUBROUTINE COMPUTES WATERSHED QUALITY CONTRIBUTIONS
      DTMIN=DELT/60.
      A=.0004*DTMIN
      B=.0025*DTMIN
      IF(TIME.EQ.TZERO+DELT) CC=0.90
      CC=CC-0.0025*DTMIN
      IF(CC.LT.0.25) CC=0.25
      DO 10 KT=1,NELT
      IF(NCHAR(KT)-1) 10,9,10
C     COMPUTE AVERAGE FLOW
    9 IF(TIME.EQ.TZERO+DELT) FLWLST(KT)=EFLOW(KT)
      LKT=KT+1
      AVFLOW=(FLWLST(KT)+EFLOW(KT))/2.0
      FLWLST(KT)=EFLOW(KT)
C     COMPUTE RUNOFF RATES IN IN/HR
      RUN1=0.0
      IF(AREA(KT).GT.0.001) RUN1=12.0*AVFLOW/AREA(KT)
      RUN2=RUN1*3600.
      IF(ISS.EQ.0) GO TO 200
      D=2.60-1.25*SQRT(RUN2)
      IF(RUN2.GT.1.0) D=1.0
      E=100.0*RUN2
      IF(E.GT.300.) E=300.
  200 DFACT=1.0-EXP(-FPSX*RUN1*DELT)
      AVAIL1=0.028+RUN2**1.6
      AVAIL2=0.057+1.4*RUN2**1.1
      IF(AVAIL1.GT.1.) AVAIL1=1.0
      IF(AVAIL2.GT.1.) AVAIL2=1.0
C     COMPUTE MATERIAL DECAYED AND MATERIAL REMAINING ON THE WATERSHED
      DO 210 J=1,NQS
      IF(J.EQ.2.AND.ISS.EQ.1) GO TO 205
      AV=1.
      IF(J.EQ.1) AV=AVAIL1
      IF(J.EQ.2) AV=AVAIL2
      POFF(LKT,J)=AV*PSHED(KT,J)*DFACT
      GO TO 206
  205 POFF(LKT,J)=10.41322*AREA(KT)*(A*E+B*E**D)*CC*PSHED(KT,J)/TOTDD(KT
     1)
  206 IF(POFF(LKT,J).GT.PSHED(KT,J)) POFF(LKT,J)=PSHED(KT,J)
      PSHED(KT,J)=PSHED(KT,J)-POFF(LKT,J)
  210 POFF(LKT,J)=POFF(LKT,J)/DELT+F1(J)*POFF(LKT,1)+F2(J)*POFF(LKT,2)
      RATE=0.0
C     COMPUTE CONCENTRATION OF WATER IN THE CATCHBASINS
```

```
* * * *
      IF(CBVOL.GT.1.0E-5.AND.BASINS(KT).GT.1.0E-15) RATE=(AVFLOW*DELT)/(
     11.6*CBVOL*BASINS(KT))
      DFACT=1.0-EXP(-RATE)
C     COMPUTE CATCHBASIN CONTRIBUTION
      DO 220 J=1,NOS
      IF(PBASIN(KT,J).LT.1.E-50) PBASIN(KT,J)=0.0
      PP=PBASIN(KT,J)*DFACT
      PBASIN(KT,J)=PBASIN(KT,J)-PP
  220 POFF(LKT,J)=POFF(LKT,J)+PP/DELT
      DO 2 L=1,NSAVE
      IF(KT-ISAVE(L))2,1,2
    1 DO 4 IP=1,NOS
    4 PML(IP)=POFF(LKT,IP)*.0001322
      PML(3)=PML(3)*60.
      WRITE(6,1000) KT,EFLOW(KT),PML
    2 CONTINUE
C1000 FORMAT(12X,I2,5X,F7.2,1X,F10.3,2X,F10.3,4X,E10.4,5(2X,F10.3)/)
 1000 FORMAT(12X,I2,5X,F7.2,1X,F10.3,2X,F10.3,4X,F10.4,5(2X,F10.3)/)    TRC CHNG
   10 CONTINUE
      RETURN
      END
```

```
* * * *
      SUBROUTINE WSHED(II)
      COMMON /GENRL/ TIME,TIME2,DELT,TZERO,AREA(99),NOS,NSTEP,TAREA,DELT
     12,MQUAL
      COMMON/WSHD/NHISTO,W5,W6,DECAY,WLMIN,WLMAX,WSTORE(3),SUMR,SUMI,SUM
     1ST
      COMMON /GULWS/ PCTZER,RAIN(4,100),ISAVE(50),NSAVE,NELT,JOUT
      COMMON /GUWSG/ EFLOW(99),EWIDTH(99),SLOPL(99),DEPTH(99,3),PCIMP(99
     1),NRG(99)
      COMMON /GUGQL/ NUP(99),IUP(99,3),NCHAR(99),G6,SUMOFF
C     THIS SUBROUTINE COMPUTES QUALITY DATA FOR A WATERSHED
C     SET RI = THE RAINFALL INTENSITY FOR THE CURRENT TIME INTERVAL
C     IF THE TIMESTEP > THE LAST RAINFALL INTERVAL SET RI=0
      DO 320 KT=1,NELT
      IF (NCHAR(KT)-1) 320,9,320
    9 RI=0.0
      IF(II-NHISTO)5,5,6
    5 L=NRG(KT)
      RI=RAIN(L,II)
    6 EFLOW(KT)=0.0
      DELR=0.0
C     THE FOLLOWING MAJOR DO LOOP COMPUTES 3 INSTANTANEOUS WATER DEPTHS
C     AND A FLOW FOR THE ENTIRE WATERSHED BASED ON THESE 3 DEPTHS
C     THESE 3 DEPTHS ARE CALCULATED FOR
C     1.....IMPERVIOUS AREA OF WATERSHED WITHOUT IMMEDIATE RUNOFF
C     2.....PERVIOUS AREA OF WATERSHED WITH INFILTRATION LOSS
C     3.....IMPERVIOUS AREA OF WATERSHED WITH IMMEDIATE RUNOFF
      DO 315 K=1,3
      IF(K-2) 201,205,210
  201 WAR=0.0
      IF(PCTZER.LT.100.0)WAR=AREA(KT)*PCIMP(KT)/10000.*(100.-PCTZER)
  202 WCON=0.0
C     CALCULATE A MODIFIED MANNING'S EQUATION
      IF(PCIMP(KT).GT.0.0)WCON=-(1.486/W5)*SQRT(SLOPE(KT))*EWIDTH(KT)*10
     10./(AREA(KT)*PCIMP(KT))
      RLOSS=0.0
      GO TO 220
  205 WAR=AREA(KT)*(100.-PCIMP(KT))/100.
      WCON=0.0
C     CALCULATE A MODIFIED MANNING'S EQUATION
      IF(PCIMP(KT).LT.100.)WCON=-(1.486/W6)*SQRT(SLOPE(KT))*EWIDTH(KT)*1
     100./(AREA(KT)*(100.-PCIMP(KT)))
      RLOSS=WLMIN
      GO TO 215
  210 WAR=AREA(KT)*PCIMP(KT)/10000.*PCTZER
      GO TO 202
  215 EXPON=DECAY*TIME2
      IF(EXPON.LT.60.)RLOSS=RLOSS+(WLMAX-WLMIN)/EXP(EXPON)
C     CALCULATE A NEW DEPTH IF ANY WATER REMAINS ON THE SURFACE AFTER
C     INFILTRATION
      IF((RI-RLOSS)*DELT+DEPTH(KT,K).GT.0.)GO TO 220
      RLOSS=RI+DEPTH(KT,K)/DELT
      DEPTH(KT,K)=0.0
      WFLOW=0.0
      GO TO 310
C     DO NOT CALCULATE FLOW IF NEW RAINFALL+OLD DEPTH<STORAGE
```

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* * * *
  220 IF((RI-RLOSS)*DELT+DEPTH(KT,K).LE.WSTORE(K))GO TO 285
C     THE FOLLOWING INNER DO LOOP CALCULATES A FLOW USING THE
C     NEWTON-RAPHSON TECHNIQUE
      DO 260 I=1,11
      DD=DEPTH(KT,K)-WSTORE(K)+.5*DELR
      IF(DD.LT.0.)DD=0.
      F=DELR-DELT*(WCON*DD**1.6666667+(RI-RLOSS))
      DF=1.-DELT*(0.83333333*WCON*DD**.6666667)
      DEL=DELR-F/DF
      IF(I.EQ.1)GO TO 240
      IF((ABS(DEL-DELR)).LT.(ABS(0.01*DELR)))GO TO 280
  240 DELR=DEL
  260 CONTINUE
      IF(DELR.LT..0001*DEPTH(KT,K))GO TO 280
      WRITE(6,1000)TIME,KT,DEPTH(KT,K),DELR
 1000 FORMAT(2X,'CHECK RESULTS , NO CONVERGENCE IN *WSHED*',F8.0,I6,2E12
     1.5)
  280 DCORR=DEPTH(KT,K)+DEL
      DELR=0.0
      WFLO=(RI-RLOSS)*WAR-(DCORR-DEPTH(KT,K))*WAR/DELT
      IF(WFLO.GT.0.)GO TO 290
  285 WFLO=0.
      DCORR=DEPTH(KT,K)+(RI-RLOSS)*DELT
  290 DEPTH(KT,K)=DCORR
C     SUM FOR TOTAL RAINFALL AND INFILTRATION
  310 SUMR=SUMR+RI*DELT*WAR
      SUMI=SUMI+RLOSS*DELT*WAR
      CFLOW(KT)=CFLOW(KT)+WFLO
  315 CONTINUE
      IF(II.NE.NSTEP)GO TO 320
      ZEROCK=0.0
      IF(PCTZER.NE.100.)ZEROCK=DEPTH(KT,1)*AREA(KT)*PCIMP(KT)/10000.*(10
     10.-PCTZER)
C     SUM FOR SURFACE STORAGE
      SUMST=SUMST+ZEROCK+DEPTH(KT,2)*(100.-PCIMP(KT))/100.
  320 CONTINUE
      RETURN
      END
```

```
* * * *
      SUBROUTINE GUTTER(II)
      COMMON /GENRL/ TIME,TIME2,DELT,TZERO,AREA(99),NOS,NSTEP,TAREA,DELT
     12,ACTUAL
      COMMON /QSHI2/ FPSX,TOTDD(99),F1(8),F2(8),CDVOL,BASINS(99),FLWLST(
     199),ISS
      COMMON /GUGOL/ NUP(99),IUP(99,3),NCHAR(99),G6,SUMOFF
      COMMON /GUWSG/ EFLOW(99),EWIDTH(99),SLOPE(99),DEPTH(99,3),PCIMP(99
     1),NRG(99)
      COMMON /GCLWS/ PCTZER,RAIN(4,100),ISAVE(50),NSAVE,NELT,JOUT
      COMMON /TFILE/ INLETS,ISFI(20),FLSV(20),PSAVE(20,8)
      DIMENSION        DFULL(99),GLEN(99),QIN(99),V(99),QSUR(99)
      EQUIVALENCE (PCIMP(1),DFULL(1)),(AREA(1),GLEN(1))
      EQUIVALENCE (TOTDD(1),QIN(1)),(BASINS(1),V(1)),(FLWLST(1),QSUR(1))
C     THIS SUBROUTINE COMPUTES QUANTITY DATA FROM PIPES
      DO 400 KT=1,NELT
      IF(NCHAR(KT)-2) 400,9,400
    9 QIN(KT)=0.0
      IF(II.EQ.1) AX1=0.0
      NU=NUP(KT)
C     ADD FLOWS FROM UPSTREAM ELEMENTS
      DO 255 JJ=1,NU
      K=IUP(KT,JJ)
  255 QIN(KT)=QIN(KT)+EFLOW(K)
C     IF ELEMENT IS THE LAST MANHOLE DO NOT COMPUTE A DEPTH OR FLOW
      DO 270 MN=1,INLETS
      IF(KT.EQ.ISFI(MN)) GO TO 391
  270 CONTINUE
      DO=DEPTH(KT,1)
      IF(QIN(KT).NE.0.) GO TO 290
      IF(DEPTH(KT,1).EQ.0.)GO TO 391
  290 IFLG=0
      DELD=0.
      AXO=(EWIDTH(KT)**2./4.)*(DO-.5*SIN(2.*DO))
      WPO=EWIDTH(KT)*DO
      IF(AXO.LT.0.)AXO=0.
      IF(WPO.LE.0.)WPO=.001
      RADO=AXO/WPO
      GCON=(1.486/G6)*SQRT(SLOPE(KT))
      FLOWO=GCON*(AXO**1.6666667)/(WPO**0.66666667)
C     THIS MAJOR DO LOOP COMPUTES A FLOW AND A DEPTH USING THE
C     NEWTON-RAPHSON TECHNIQUE
      DO 360 I=1,30
      DI=DEPTH(KT,1)+DELD
      IF(I.GT.1)GO TO 307
      DI=1.5707963
      DELD=DI-DEPTH(KT,1)
  307 IF(DI.GT.0.)GO TO 308
      DI=0.
      DELD=-DEPTH(KT,1)
  308 IF(DI.LE.DFULL(KT))GO TO 310
      DI=DFULL(KT)
      DELD=DI-DEPTH(KT,1)
  310 DELV=GLEN(KT)*(EWIDTH(KT)**2./4.)*(DELD-.5*SIN(2.*DI)+.5*SIN(2.*DO
     1))
      DDELV=GLEN(KT)*(EWIDTH(KT)**2./4.)*(1.-COS(2.*DI))
```

```
* * * *
      AX1=(EWIDTH(KT)**2./4.)*(DI-.5*SIN(2.*DI))
      DAX1=(EWIDTH(KT)**2./4.)*(1.-COS(2.*DI))
      WP1=EWIDTH(KT)*DI
      DWP1=EWIDTH(KT)
      IF(AX1.LT.0.)AX1=0.
      IF(WP1.LE.0.)WP1=.001
      RAD1=AX1/WP1
      FLOW1=GCON*(AX1**1.6666667)/(WP1**0.66666667)
      FLOW=.5*(FLOWD+FLOW1)
      DFLOW1=.5*GCON*(1.6666667*(RAD1**.66666667)*DAX1-.66666667*(RAD1**
     11.6666667)*DWP1)
      F=DELV*DELT*(FLOW-QIN(KT))-QSUR(KT)
      DF=DDELV*DELT*DFLOW1
      IF(DF.GT.1.0E-10)GO TO 320
      DEL=.01
      GO TO 340
  320 DEL=DELD-F/DF
  340 IF(I.EQ.1)GO TO 360
      IF(DEPTH(KT,1)+DEL.LT.DFULL(KT))GO TO 355
      IF(IFLG.EQ.1)GO TO 390
      DEL=DFULL(KT)-DEPTH(KT,1)
      IFLG=1
      GO TO 360
  355 IFLG=0
C     CHECK TO SEE IF GUTTER CONVERGED
      IF(ABS(F).LT.0.1)GO TO 380
  360 DELD=DEL
      WRITE(6,1000)TIME,KT,DEPTH(KT,1),DELD
 1000 FORMAT(2X,'CHECK RESULTS , NO CONVERGENCE IN *GUTTER*',F8.0,I6,2E1
     12.5)
  380 DELD=DEL
      DEL=0.0
C     CALCULATE NEW DEPTH
      DEPTH(KT,1)=DEPTH(KT,1)+DELD
      QSUR(KT)=0.
      IF(FLOW.LT.1.0E-10)FLOW=0.0
      EFLOW(KT)=FLOW
      GO TO 392
  390 DEPTH(KT,1)=DFULL(KT)
      EFLOW(KT)=FLOW1
      QSUR(KT)=QSUR(KT)+(QIN(KT)-FLOW)*DELT
      IF(QSUR(KT).LT.0.)QSUR(KT)=0.
      GO TO 392
  391 EFLOW(KT)=QIN(KT)
  392 V(KT)=AX1*GLEN(KT)
  400 CONTINUE
      RETURN
      END
```

```
* * * *
      SUBROUTINE DRYWF
      COMMON /TIT/ TITLE(40)
      COMMON /GENRL/ TIME,TIME2,DELT,TZERO,AREA(24),NDS,NSTEP,TAREA,DELT
     12,MQUAL
      COMMON /GOLWS/ PCTZER,RAIN(4,100),ISAVE(50),NSAVE,NELT,JOUT
      COMMON /TFILE/ INLETS,ISFI(20),FLSV(20),PSAVE(20,8)
      DIMENSION DDWF(4,24)
C     THIS SUBROUTINE COMPUTES DRY WEATHER FLOW
C     BOD,SUS SOL, AND COLIFORMS ARE THE MAJOR CONSTITUENTS INVOLVED IN
C     DRY WEATHER FLOW
C     HOWEVER, ANY 3 POLLUTANTS MAY BE CHOSEN JUST BY SWITCHING
C     THEIR POSITION IN THE NEEDED VECTORS TO EITHER 2,3, OR 4.
C     READ DRY WEATHER FLOW AND POLLUTANT CONCENTRATION FACTORS
      READ(5,101) DWF,CBOD,CSS,CCOLI
C     READ DIURNAL VARIATION BASED ON A 24 HOUR CYCLE
      DO 200 I=1,4
  200 READ(5,101) (DDWF(I,J),J=1,24)
C     JOUT=INPUT FILE
C     JOUTT=OUTPUT FILE
      READ(JOUT) TITLE
      JOUTT=JOUT+1
      WRITE(JOUTT) TITLE
      READ (JOUT)    NTIM,NINPUT, NPOLL, DTIM, TZERO
      WRITE(JOUTT) NTIM,NINPUT,NPOLL,DTIM,TZERO
      IDTIM=(TZERO/3600.)+1.0
      READ(JOUT) NOUT
      WRITE(JOUTT) NOUT
C     READ FLOW AND POLLUTANT MASS LOADS CALCULATED DURING WET WEATHER
      DO 210 I=1,NTIM
      READ(JOUT) DTIM,RUNOFF,POLL1,POLL2,POLL3
C     .00374=CONVERSION FACTOR (LBS/MG*L/FT3*SEC/MIN)
      TDWF=DWF*.00374
C     ADD DRY WEATHER FLOW TO WET WEATHER FLOW
      RUNOFF=RUNOFF+DWF*DDWF(1,IDTIM)
C     CALCULATE POLLUTANT MASS LOADS FROM DRY WEATHER FLOW AND ADD TO
C     WET WEATHER MASS LOADS
      POLL1=POLL1+CBOD*DDWF(2,IDTIM)*TDWF
      POLL2=POLL2+CSS*DDWF(3,IDTIM)*TDWF
      POLL3=POLL3+CCOLI*DDWF(4,IDTIM)*TDWF
      IDTIM=IDTIM+1
C     WRITE COMBINED FLOW AND TOTAL MASS LOADS FROM DRY AND WET WEATHER
C     CONDITIONS
      WRITE(JOUTT) DTIM,RUNOFF,POLL1,POLL2,POLL3
  210 WRITE(6,102) DTIM,RUNOFF,POLL1,POLL2,POLL3
  101 FORMAT(8F10.5)
  102 FORMAT(5X,5(1PE11.4))
      RETURN
      END
```

```
* * * *
      PROGRAM LNKPRG
      DIMENSION TITLE(20),PTLE(22)
      DIMENSION TPOL(20,8),PSAVE(20,8),TFLO(20),FLSV(20),PPRT(11),NPIN(2
     10,8),NPOT(20,8),NPOLL(20),ISFI(20)
      DIMENSION  ZERO(12)                                               TRC  NEW
      DIMENSION NAPS(10), FLO(10), APSP(10,11)                          TRC  NEW
      DATA ZERO/12*0.0/                                                 TRC  NEW
C                                                                       TRC  NEW
C         NOPS      NUMBER OF ADDITIONAL POINT SOURCES                  TRC  NEW
C         TFIN      FINAL INPUT AT END OF RECEIV = LAST TIME STEP       TRC  NEW
C         APSP      ADDITIONAL POINT SOURCE MASS LOADINGS               TRC  NEW
C                                                                       TRC  NEW
      WRITE(6,200)
C.........READ SSWMM OUTPUT FILE
      READ(5,100) IFL,IFO
C.........READ FROM FILE GENERAL STORM AND BASIN INFORMATION
      REWIND IFO
      REWIND IFL
      READ(IFL) TITLE
      WRITE(6,140) TITLE
      READ(IFL) NSTEP,INLETS,NPFI,SDELT,SZERO,TAREA
      READ(IFL) (ISFI(I),I=1,INLETS)
C.........INITIALIZE TIME TO SSWMM START TIME AND COMPUTE
C...........THE HOUR AND MINUTES OF TIME INITIALIZATION
      TIME=SZERO
      IHR=SZERO/3600.
      IMN=(SZERO-FLOAT(IHR)*3600.)/60.
      WRITE(6,150) INLETS,NSTEP,IHR,IMN
      TADD=0.0
C.........READ RECEIV TIMING INFORMATION
      READ(5,110) RZERO,RDELT,ISDY
      WRITE (6,6000)   RZERO, RDELT, ISDY                               TRC  NEW
      IF (ISDY.NE.0)   TADD = 86400.                                    TRC CHNG
C.........IF SSWMM START TIME BEGINS ON THE DAY AFTER RECEIV START TIME,
C...........SET TADD=86400. (86400 SEC=24 HOURS)
    1 WRITE(6,170)
C.........READ THE # OF POLLUTANTS PASSED AND I-O ARRAY POSITIONING
C...........FROM SSWMM TO RECEIV
      READ(5,120) (NPOLL(I),I=1,INLETS)
      DO 3 I=1,INLETS
      J=NPOLL(I)
      READ(5,120) (NPIN(I,K),K=1,J)
      READ(5,120) (NPOT(I,K),K=1,J)
      WRITE(6,160) I,J,(NPIN(I,K),K=1,J)
    3 WRITE(6,165) (NPOT(I,K),K=1,J)
      READ(5,195) PTLE
C.........INITIALIZE TIME-STEP RECORD COUNTER TO 0
      KT=0
      MLL = 1                                                           TRC CHNG
C
      READ (5,100)   NOPS, TFIN                                         TRC CHNG
      THR = 0.0
      WRITE (6,180)   THR, PTLE
      DO 450  I=1,NOPS
      READ (5,130)  NAPS(I), FLO(I), (APSP(I,J),J=1,11)                 TRC  NEW
```

```
* * * *
      WRITE(6,410)  NAPS(I), FLO(I), (APSP(I,J),J=1,11)                  TRC  NE
  450 WRITE (IFO)       MOL, THR, NAPS(I), FLO(I), (APSP(I,J),J=1,11)    TRC  NE
      IF (RDELT.GT.SDELT)   GO TO 17
      WRITE  (IFO)        MOL, ZERO(1), MOL, (ZERO(I),I=1,12)            TRC CHN
      DO 18    INDEX=1,NSTEP                                             TRC CHN
      READ(IFL) TIME,(FLSV(MN),MN=1,INLETS),((PSAVE(MN,N),N=1,NPFI),MN=1
     1,INLETS)
      THR = (TIME+TADD)/3600.
      WRITE (6,400)    TIME,PTLL
      DO 18    I=1,INLETS
      DO 19    N=1,11
   19 PPRT(N) = 0.0
      FSUM = FLSV(I)*0.028317
      NPWT = NPOLL(I)
      DO 20    J=1,NPWT
      K = NPIN(I,J)
      L = NPOT(I,J)
C     IF (K.NE.3)    GO TO 30
C     PPRT(L) = PSAVE(I,3)*1.666E-08                                     TRC CHN
C     GO TO 20                                                           TRC CHN
   30 PPRT(L) = PSAVE(I,K)*7559.87                                       TRC CHN
   20 CONTINUE
      WRITE(6,410) I,FSUM,(PPRT(L),L=1,11)
   18 WRITE(IFO)      MOL,THR,I,FSUM,(PPRT(L),L=1,11)                    TRC CHN
      GO TO 15
C
   17 IFIN=0
      ICNT=0
C........SET TOTAL FLOWS AND POLLUTANTS TO 0 FOR EACH INLET
      DO 111 I=1,INLETS
      TFLO(I)=0.0
      DO 111 J=1,8
      TPOL(I,J)=0.0
      IF(I-1) 111,112,111
C     THIS IS A DUMMY CARD TO INITIALIZE FIRST QUAN AND QUAL
C     SETUP RECORD TO ZERO
  112 WRITE(IFO)      MOL,TFLO(1),I,TFLO(1),(TPOL(1,I),I=1,11)           TRC CHN
  111 CONTINUE
C........CALCULATE THE # OF RECEIV TIME-STEPS OCCURRING BEFORE
C..........SSWMM START-UP TIME
   22 TDIFF=(TIME+TADD-RZERO)/RDELT
      NTDF=TDIFF
      FDIFF=TDIFF-FLOAT(NTDF)
C........THE FOLLOWING PROCEDURE IS AN INITIALIZATION STEP
C..........THAT IS ONLY NECESSARY WHEN THE START UP OF SSWMM DOES
C..........NOT OCCUR AT THE SAME TIME OF A RECEIV TIME-STEP
      IF(FDIFF) 33,44,33
   33 ICNT=1
      READ(IFL) TIME,(FLSV(MN),MN=1,INLETS),((PSAVE(MN,N),N=1,NPFI),MN=1
     1,INLETS)
      DO 5 I=1,INLETS
      TFLO(I)=TFLO(I)+FLSV(I)
      NPWT=NPOLL(I)
      DO 5 J=1,NPWT
      K=NPIN(I,J)
```

```
* * * *
    5 TPOL(I,K)=TPOL(I,K)+PSAVE(I,K)
      KT=KT+1
      GO TO 22
C........CALCULATE THE # OF SSWMM TIME-STEPS IN A RECEIV TIME-STEP
   44 NTSW=RDELT/SDELT
C........PASS TO CONVERTING AND PRINTING ROUTINES IF FLOWS
C...........AND POLLUTANTS WERE INITIALIALLY SUMMED AND AVERAGED
C...........OTHERWISE SUM AND AVERAGE SSWMM QUALITY AND QUANTITY
C...........TIME-STEP INFORMATION FOR EACH INLET
C...........OVER EACH RECEIV TIME-STEP
      IF(ICNT) 222,16,222
  333 DO 4 I=1,INLETS
      TFLO(I)=0.0
      DO 4 J=1,6
    4 TPOL(I,J)=0.0
C........FLOWS AND POLLUTANT MASS LOADS ARE SUMMED FOR EACH INLET FOR AS
C...........MANY TIME-STEPS AS NECESSARY UNTIL A SSWMM TIME-STEP OCCURS
C...........AT THE SAME TIME AS A RECEIV TIME-STEP.
C........FLOWS AND POLLUTANT MASS LOADS ARE THEN AVERAGED
C...........OVER THE RECEIV TIME STEP LENGTH
   16 DO 55 IT=1,NTSW
      READ(IFL) TIME,(FLSV(MN),MN=1,INLETS),((PSAVE(MN,N),N=1,NPFI),MN=1
     1,INLETS)
      DO 6 I=1,INLETS
      TFLO(I)=TFLO(I)+FLSV(I)
      NPWT=NPOLL(I)
      DO 6 J=1,NPWT
      K=NPIN(I,J)
    6 TPOL(I,K)=TPOL(I,K)+PSAVE(I,K)
      KT=KT+1
C........CHECK FOR END OF FILE
      IF(KT-NSTEP) 55,7,55
   55 CONTINUE
      GO TO 222
C........IF THE LAST SSWMMM TIME-STEP DOES NOT OCCUR AT THE
C...........SAME TIME AS THE NEXT RECEIV TIME-STEP, ADD AS MANY SSWMM
C...........TIME-STEPS UNTIL BOTH TIME STEPS OCCUR TOGETHER
    7 TDIFF=(TIME+TADD-RZERO)/RDELT
      NTDF=TDIFF
      FDIFF=TDIFF-FLOAT(NTDF)
      IF(FDIFF) 13,12,13
   13 TIME=TIME+SDELT
      GO TO 7
   12 IFIN=1
  222 THR=(TIME+TADD)/3600.
      TIME = TIME + TADD
      WRITE(6,400) TIME,PTLE                                             TRC  NEW
      DO 8 I=1,INLETS
      DO 88 N=1,11
   88 PPRT(N)=0.0
C........CONVERT FLOW TO M3/SEC
      FSUM=TFLO(I)*.028317/NTSW                                          TRC CHNG
      NPWT=NPOLL(I)
      DO 11 J=1,NPWT
      K=NPIN(I,J)
```

```
* * * *
      L=NPOT(I,J)
C     IF(K-3) 9,10,9                                                    TRC CHNG
C.........CONVERT F. COLIFORMS TO 10**6 MPN/SEC
C  10 PPRT(L)=TPOL(I,3)*1.666E-08/NTSW                                  TRC CHNG
C     GO TO 11                                                          TRC CHNG
C.........CONVERT OTHER POLLUTANTS TO MG/SEC
    9 PPRT(L)=TPOL(I,K)*7559.87/NTSW
   11 CONTINUE
      WRITE(6,410) I,FSUM,(PPRT(L),L=1,11)
    8 WRITE(IFO)     MQL,THR,I,FSUM,(PPRT(L),L=1,11)                    TRC CHNG
      IF(IFIN) 15,333,15
   15 DUM=99999.
      WRITE (6,180)   TFIN, PTLE                                        TRC  NEW
      DO 421   I=1,NOPS                                                 TRC  NEW
      WRITE (6,410)   NAPS(I), FLO(I), (APSP(I,J),J=1,11)               TRC  NEW
      WRITE (IFO)     MQL, TFIN, NAPS(I), FLO(I), (APSP(I,J),J=1,11)    TRC  NEW
  421 CONTINUE                                                          TRC  NEW
      WRITE(IFO)     MQL, DUM                                           TRC CHNG
      REWIND IFO
      REWIND IFL
  100 FORMAT (I5, F5.0)                                                 TRC CHNG
  110 FORMAT (2F5.0,I5)
  130 FORMAT (I5, F5.2, F8.0,/10F8.0)
  140 FORMAT (/////,10X,'SSWMM OUTPUT FILE CONTAINS FLOWS AND POLLUTANT
     1MASS LOADS FROM',//,10X,20A4)
  145 FORMAT (22A3)
  150 FORMAT (/////,10X,'THIS BASIN CONTAINS',2X,I2,2X,'INLETS',//,10X,'
     1OUTPUT FILE CONTAINS RESULTS FOR',2X,I2,2X,'RAINFALL STEPS',//,10X
     2,'STORM START-UP TIME IS AT',2X,2I2)
  170 FORMAT (1H1,//,10X,'INLET',10X,'# POLL',15X,'POSITION OF POLLUTANT
     1S IN THE INPUT AND OUTPUT ARRAYS',//,43X,'#1',3X,'#2',3X,'#3',3X,'
     2#4',3X,'#5',3X,'#6',3X,'#7',3X,'#8',//)
  160 FORMAT (/,12X,I2,13X,I2,11X,8(3X,I2))
  165 FORMAT(/,40X,8(3X,I2)/)
  180 FORMAT (1H1, 2X, 'BACKGROUND INFORMATION AT TIME =', 2X, F6.0, 2X,
     X        'IS AS FOLLOWS'/       10X, 'FLOW IN CU M/SEC'/ 10X,      TRC CHNG
     2             'POLLUTANT LOADINGS IN MG/SEC; COLIFORMS (IF MODELED)'TRC  NEW
     3           , ' IN MPNE+06/SEC.'                                   TRC  NEW
     X                       //5X, 'PTSRC', 6X, 'FLOW', 11(3X,2A3)//)
  120 FORMAT (10I5)
  200 FORMAT (1H1,///,10X,'PROGRAM TO INTERPRET SSWMM OUTPUT FILE TO INP
     1UT INTO SETUP BLOCK OF RECEIV II MODEL')
  400 FORMAT (1H1,//,10X,'INPUT INTO RECEIV II AT TIME',2X,F6.0,2X,'SEC'
     1        ,2X, 'ARE AS FOLLOWS'/10X, 'FLOW IN CU M/SEC'/ 10X,       TRC CHNG
     2             'POLLUTANT LOADINGS IN MG/SEC; COLIFORMS (IF MODELED)'TRC  NEW
     3           , ' IN MPNE+06/SEC.'// 5X, 'INLET', 6X, 'FLOW',        TRC CHNG
     4          11(3X,2A3)//)                                           TRC CHNG
      STOP
  410 FORMAT (/7X,I2,F11.4,11(1X,F8.1))                                 TRC CHNG
 6000 FORMAT (/ 10X, 'RECEIVE START TIME ', F6.0//                      TRC  NEW
     X             10X, 'RECEIVE TIME STEP  ', F6.0//                   TRC  NEW
     X             10X, 'ISDY = ', I5)                                  TRC  NEW
      END
```

```
* * * *
      PROGRAM QUANT
C
C
C                                           BASIN MODEL TEST PROGRAM
C
C
C                                           COMMON BLOCKS TO ZERO ARRAYS
      COMMON /CONTR/ IZ(22)
      COMMON /HEADS/ IZZ(622)
      COMMON         IZZZ(8928)
C
C                                           TAPE FILES
C
      COMMON/TAPES/INCNT,IOUTCT,JIN(10),JOUT(10),NSCRAT(5)
      INTEGER RUN
C
C                                           ZERO ARRAYS
C
      DO 100 I=1,22
  100 IZ(I)=0
      DO 200 I=1,622
  200 IZZ(I)=0
      DO 300   I=1,8928
  300 IZZZ(I)=0
C
C                                           SETUP TAPE FILES
C
      N5=5
      N6=6
      INCNT=0
      IOUTCT=0
      JIN(1) = 23
      JOUT(1) = 24
      NSCRAT(1) = 25
      NSCRAT(2) = 26
      NSCRAT(3) = 27
      NSCRAT(4) = 28
      LFILE = 21
      READ(N5,1001) RUN
 1001 FORMAT (I1)
      IF (RUN.EQ.1)   GO TO 2
      CALL SETUP  (N5,N6,JIN(1),LFILE)
    2 CALL REFLOW
      STOP 1111
      END
```

```
* * * *
      SUBROUTINE REFLOW
      COMMON /TAPES/ INCNT,IOUTCT,JIN(10),JOUT(10),NSCRAT(5)            RECE   2
      DIMENSION QUAN(2),QUAL(2),ANAME(4)                                 RECE   3
      DATA QUAN(1),QUAN(2)/4HQUAN,4HTITY/                                RECE   4
      DATA QUAL(1),QUAL(2)/4HQUAL,4HITY /                                RECE   5
      N5=5                                                               RECE   6
      N6=6                                                               RECE   7
      INCNT=INCNT+1                                                      RECE   8
      READ (N5,100) (ANAME(I),I=1,4)                                     RECE   9
  100 FORMAT(4A4,I4)                                                     RECE  10
      IF (ANAME(1).EQ.QUAN(1).AND.ANAME(2).EQ.QUAN(2)) CALL SWFLOW       RECE  11
  400 WRITE(N6,500)                                                      RECE  17
  500 FORMAT (31H0RECEIVING SIMULATION COMPLETED)                        RECE  18
      RETURN                                                             RECE  19
      END                                                                RECE  20
```

```
* * * *
      SUBROUTINE SETUP (N5,N6,N21,N22)
      INTEGER TYPE
      DIMENSION TITLE(40),ISW(100),NS(100,10),CONST(11),PTIME(150),
     1Q(150),QNODE(100),WITH(100),PARAM(150,11),TYPE(150),CT(11,100)
      READ(N5,1001) (TITLE(I),I=1,40)
 1001 FORMAT(20A4)
      WRITE(N6,2001) (TITLE(I),I=1,40)
 2001 FORMAT(1H1,20A4/1H ,20A4)
      REWIND N21
      REWIND N22
      WRITE(N21) (TITLE(I),I=1,40)
      READ(N5,1002) MJSW,TZERO,NSTEPS
 1002 FORMAT(I5,F10.0,I5)
      WRITE(N6,2002) MJSW,TZERO,NSTEPS
 2002 FORMAT(6H MJSW=,I5,8H  TZERO=,F10.2,9H  NSTEPS=,I5)
      DUMMY=0.0
      IDUP=0
      TZERO=TZERO*3600.
      NCON=11
      WRITE(N21) NSTEPS,MJSW,NCON,DUMMY,TZERO,DUMMY
      WRITE(N6,2003)
 2003 FORMAT(26H0 NODE  SOURCES ASSOCIATED)
      DO 20 L=1,MJSW
      DO 10 K=1,10
   10 NS(L,K)=0
      READ(N5,1003) ISW(L),(NS(L,K),K=1,10)
 1003 FORMAT(11I5)
      WRITE(N6,2004) ISW(L),(NS(L,K),K=1,10)
 2004 FORMAT(1H ,11I5)
   20 CONTINUE
      WRITE(N21) (ISW(L),L=1,MJSW)
      NINREC=0
      TTIME=0.0
      DO 25 NN=1,150
   25 PTIME(NN)=-1.0
   30 READ(N22)       MASS,T,NSOURC,FLOW,(CONST(K),K=1,11)
      TIME=T*3600.
      IF(T.GT.9999.) GO TO 50
      IF(TIME.EQ.PTIME(NSOURC)) GO TO 80
      IF(TIME.NE.TTIME) GO TO 50
   40 PTIME(NSOURC)=TIME
      Q(NSOURC)=FLOW
      DO 45 K=1,11
   45 PARAM(NSOURC,K)=CONST(K)
      TYPE(NSOURC)=MASS
      GO TO 30
   50 DO 70 L=1,MJSW
      QNODE(L)=0.0
      WITH(L)=0.0
      DO 52 KK=1,11
   52 CT(KK,L)=0.0
      DO 60 K=1,10
      N=NS(L,K)
      IF(N.EQ.0) GO TO 60
      QNODE(L)=QNODE(L)+Q(N)
```

```
* * * *
      IF(Q(N).LT.0.0) GO TO 58
      DO 56 KK=1,11
      IF (TYPE(N).EQ.1)    GO TO 54
      CT(KK,L)=CT(KK,L)+PARAM(N,KK)*Q(N)
      GO TO 56
   54 CT(KK,L)=CT(KK,L)+PARAM(N,KK)/1000.
   56 CONTINUE
      GO TO 60
   58 WITH(L)=WITH(L)-Q(N)
   60 CONTINUE
   70 CONTINUE
      WRITE(N21) TTIME,(QNODE(L),WITH(L),(CT(K,L),K=1,11),L=1,MJSW)
      TTIME=TIME
      NINREC=NINREC+1
      IF(T    .LE.9999.) GO TO 40
      REWIND N22
      IF(NINREC.EQ.NSTEPS) RETURN
   80 WRITE(N6,2005) NSOURC,T
 2005 FORMAT(22H0TIME ERROR ON SOURCE ,I4,8H AT TIME,F10.2)
      STOP
      END
```

* * * *

```
      SUBROUTINE TRIAN(IT,JJ,KK,LL)
C                                           SUBROUTINE TRIAN
C                                           HYDRODYNAMICS PROGRAM
C                                           SPECIFICATION STATEMENTS
C
C
C                                           CONTROL
C
      COMMON /CONTR/ N5,N6,N20,N21,  NTCYC,NQCYC,NHCYC,  NT,NOSWRT
     1,  DELTQ,DELT,TZERO,   ISWCH(10)
C
C                                           GENERAL
C
      COMMON  ALPHA(50),  NJ,NC,   ICYC,KCYC,NCYC,   WIND,WDIR,EVAP
     1,  PRECP(50),NEXIT
C
C                                           JUNCTIONS
C
      COMMON H(10), HN(10), HT(10), HBAR(10), HAVE(10), NCHAN(10,8),
     1       IPCINT(10,8), AS(10), VOL(10), X(10), Y(10), DEP(10),
     2       COF(10), QIN(10), QOU(10), QINST(10), QINBAR(10),
     3       QOUBAR(10)
C
C                                           CHANNELS
C
      COMMON LEN(10), NJUNC(10,2), B(10), R(10), A(10), AT(10), AK(10),
     1       Q(10), QBAR(10), QAVE(10), V(10), VT(10), VBAR(10),
     2       FWIND(10), NUMCH(10), NTEMP(6), NCLOS(10), RBAR(10)
C
C                                           PRINTOUT AND PLOTTING
C
      COMMON NPRT, IPRT, NHPRT, JPRT(10), PRTH(250,10), NQPRT, CPRT(10),
     1       PRTV(250,10), PRTQ(250,10), IDUM(12), ICOL(10), LTIME,
     2       NPLT, NPDEL, JPLT(10), HPLT(10)
C
C                                           STAGE-TIME COEFFICIENTS
C
      COMMON YY(50) ,TT(50) ,AA(10),XX(10),SXX(10,10),SXY(10)
     1,A1,A2,A3,A4,A5,A6,A7,PERIOD,JGW
C
C                                           STORMWATER
C
      COMMON  TITLE(30),NJSW,QE(20,2),JSW(20)
     2, RAIN(100),INTIME(100),INRAIN,JBOUND(20),JJBOUN
C
C                                           TAPES
C
      COMMON /TAPES/ INCNT,IOUTCT,JIN(10),JOUT(10),NSCRAT(5)
C
C
      COMMON/TRI/T(5),NX(5)
C
C
C                                           TYPE DESIGNATIONS
C
```

```
* * * *
      INTEGER CPRT
      REAL LEN
      IF(II.NE.0) GO TO 300
C
C
C                                          ZERO POINTER ARRAY
      DO 250 I=1,NJ
      DO 250J=1,8
      IPOINT(I,J)=0
      NCHAN(I,J)=0
  250 CONTINUE
      RETURN
C
C
C                                          SET UP TRIANGLE PARAMETERS
  300 CONTINUE
      NX(1)=II
      NX(2)=JJ
      NX(3)=KK
      NX(4)=II
      NX(5)=JJ
      T(1) = (X(JJ) - X(KK))**2 + (Y(JJ) - Y(KK))**2
      T(2) = (X(KK) - X(II))**2 + (Y(KK) - Y(II))**2
      T(3) = (X(II) - X(JJ))**2 + (Y(II) - Y(JJ))**2
      T(4)=T(1)
      T(5)=T(2)
C
C
C                                          DO ALL THREE SIDES
      NB=2
      IF(LL.EQ.0) NB=1
      DO 600 N=1,3,NB
C
C
C                                          LOCATE CHANNELS ON POINTER ARRAY
      I=MIN0(NX(N+1),NX(N+2))
      J=MAX0(NX(N+1),NX(N+2))
      DO 350 K=1,8
      IF(IPOINT(I,K).EQ.J) GO TO 370
      IF(IPOINT(I,K).EQ.0) GO TO 360
  350 CONTINUE
  360 IPOINT(I,K)=J
      NC=NC+1
      NCHAN(I,K)=NC
  370 M=NCHAN(I,K)
C
C
C                                          M IS CHANNEL NUMBER JUST
C                                          ASSIGNED
      NJUNC(M,1)=I
      NJUNC(M,2)=J
      SUB=T(N+1)+T(N+2)-T(N)
      G=SQRT(T(N))/2.
      LEN(N)=2.*G
      C=G/SQRT(4.*T(N+2)*T(N+1)-SUB**2)*SUB
      G=G/2.*C
```

```
* * * *
      AS(I)=AS(I)+G
      AS(J)=AS(J)+G
      IF(C.LE.0.) WRITE(6,102) M,C
  102 FORMAT(27H NEGATIVE WIDTH CHANNEL NO.,I5,10H   WIDTH =,E12.4)
      B(M)=B(M)+C
      R(M)=(DEP(I)+DEP(J))/2.
      A(M)=B(M)*R(M)
      AK(M)=(COF(I)+COF(J))/2.
      V(M)=0.
  600 CONTINUE
      IF(LL.EQ.0) RETURN
      DO 750 NN=3,4
      I=MIN0(NX(NN),LL)
      J=MAX0(NX(NN),LL)
      DO 620 K=1,8
      IF(IPOINT(I,K).EQ.J) GO TO 640
      IF(IPOINT(I,K).EQ.0) GO TO 630
  620 CONTINUE
  630 IPOINT(I,K)=J
      NC=NC+1
      NCHAN(I,K)=NC
  640 M=NCHAN(I,K)
      NJUNC(M,1)=I
      NJUNC(M,2)=J
      SUB=T(3)+T(4)-T(2)
      G=SQRT(T(2))/2.
      LEN(M)=G
      C=G/SQRT(4.*T(3)*T(4)-SUB**2)*SUB
      G=G/2.*C
      AS(I)=AS(I)+G/2.
      AS(J)=AS(J)+G/2.
      IF(C.LE.0.) WRITE(6,102) M,C
      B(M)=B(M)+C
      R(M)=(DEP(I)+DEP(J))/2.
      A(M)=B(M)*R(M)
      AK(M)=(COF(I)+COF(J))/2.
      V(M)=0.
  750 CONTINUE
      RETURN
      END
```

```
* * * *
      SUBROUTINE TIDCF(ITIDE,KO,NI,MAXIT,NCHTID)
C                                                                          TIDC   1
C                                                                          TIDC   2
C                                       STAGE TIME COEFFICIENTS            TIDC   3
C                                       HYDRODYNAMICS PROGRAM              TIDC   4
C                                       SPECIFICATION STATEMENTS           TIDC   5
C                                                                          TIDC   6
C                                                                          TIDC   7
C                                       CONTROL                            TIDC   8
      COMMON /CONTR/ N5,N6,N20,N21,  NTCYC,NQCYC,NHCYC,  NT,NQSWRT         TIDC   9
     1,  DELTQ,DELT,TZERO,   ISWCH(10)                                     TIDC  10
C                                                                          TIDC  11
C                                                                          TIDC  12
C                                       GENERAL                            TIDC  13
      COMMON  ALPHA(30),  NJ,NC,   ICYC,KCYC,NCYC,   WIND,WDIR,EVAP        TIDC  14
     1,  PRECP(50),NEXIT                                                   TIDC  15
C                                                                          TIDC  16
C                                                                          TIDC  17
C                                       JUNCTIONS                          TIDC  18
      COMMON H(10), HN(10), HT(10), HBAR(10), HAVE(10), NCHAN(10,8),       TIDC  19
     1       IPOINT(10,8), AS(10), VOL(10), X(10), Y(10), DEP(10),
     2       COF(10), QIN(10), QOU(10), QINST(10), QINBAR(10),
     3       QOUBAR(10)
C
C                                                                          TIDC  24
C                                       CHANNELS                           TIDC  25
      COMMON LEN(10), NJUNC(10,2), B(10), R(10), A(10), AT(10), AK(10),    TIDC  26
     1       Q(10), QBAR(10), QAVE(10), V(10), VT(10), VBAR(10),
     2       FWIND(10), NUMCH(10), NTEMP(8), NCLOS(10), RBAR(10)
C
C                                                                          TIDC  31
C                                       PRINTOUT AND PLOTTING              TIDC  32
      COMMON NPRT, IPRT, NHPRT, JPRT(10), PRTH(250,10), NQPRT, QPRT(10),   TIDC  33
     1       PRTV(250,10), PRTQ(250,10), IDUM(12), ICOL(10), LTIME,
     2       NPLT, NPDEL, JPLT(10), HPLT(10)
C
C                                                                          TIDC  37
C                                       STAGE-TIME COEFFICIENTS            TIDC  38
      COMMON YY(50) ,TT(50) ,AA(10),XX(10),SXX(10,10),SXY(10)              TIDC  39
     1,A1,A2,A3,A4,A5,A6,A7,PERIOD,JGW                                     TIDC  40
C                                                                          TIDC  41
C                                                                          TIDC  42
C                                       STORMWATER                         TIDC  43
      COMMON TITLE(30),NJSW,QF(20,2),JSW(20)                               TIDC  44
     2, RAIN(100),INTIME(100),NRAIN,JBOUND(20),JJBOUN                      TIDC  45
C                                                                          TIDC  46
C                                                                          TIDC  47
C                                       CONTROLLED OR FORCED NODES         TIDC  48
      COMMON/HEADS/NTIDE,JTIDE(15),TIDE(15,7),NDAM,JDAM(50,2),             TIDC  49
     1DAM(50,3),DELHA(10),SPILL(10)),SPLBAR(10)                            TIDC  50
C                                                                          TIDC  51
C                                                                          TIDC  52
C                                       TAPES                              TIDC  53
      COMMON /TAPES/ INCNT,IOUTCT,JIN(10),JOUT(10),NSCRAT(5)               TIDC  54
C                                                                          TIDC  55
                                                                           TIDC  56
```

```
* * * *
C
C
C                                  TIDE COEFFICIENTS
C
C
C                                  TYPE DESIGNATION
      INTEGER CPRT
      REAL LEN
C
C
C
C                                  TIDAL CURVE FIT, 7 TERM
                                   SINUSOIDAL EQUATION
      WRITE(N6,130) JTIDE(ITIDE)
  130 FORMAT(17H0 FOR TIDAL NODE ,I3)
      WRITE (N6,140) KO,NI,MAXIT,NCHTID
  140 FORMAT  (7H0 KO IS,I3,19H NUMBER OF TERMS IS,I4,32H MAXIMUM NUMBER
     1 OF ITERATIONS IS,I4,21H TIDE CHECK SWITCH IS,I2)
C                                  IF KO EQUALS ONE, PROGRAM WILL
C                                  READ FOUR POINTS OF INFORMATION
C                                  AND EXPAND THEM FOR A FULL TIDE
C
C                                  NI IS THE NUMBER OF INFORMATION
C                                  POINTS
C                                  MAXIT IS THE MAXIMUM NUMBER OF
C                                  ITERATIONS
C                                  IF NCHTID EQUALS ONE, TIDAL
C                                  INPUT-OUTPUT WILL BE PRINTED
C
C                                  DELTA IS THE ACCURACY
C                                  LIMIT IN FEET
      DELTA = 0.005
      NTT=7
      W = 2.*3.14159 /PERIOD
      IF(KO.EQ.0) GO TO 225
      TT(50) =TT(1)+PERIOD
      YY(50)=YY(1)
      DO 220 I=1,4
      J=I+1
      IF (J.GT.4) J=50
      NI=NI+1
      TT(NI)=(3.*TT(I)+TT(J))/4.
      YY(NI)=0.8535*YY(I)+0.1465*YY(J)
      NI=NI+1
      TT(NI)=(TT(I)+TT(J))/2.
      YY(NI)=(YY(I)+YY(J))/2.
      NI=NI+1
      TT(NI)=(TT(I)+3.*TT(J))/4.
      YY(NI)=0.1465*YY(I)+0.8535*YY(J)
  220 CONTINUE
  225 CONTINUE
      IF (NCHTID.NE.1) GO TO 240
      WRITE (N6,146)
  146 FORMAT (29H0 NO.        TIME           VALUE   )
      WRITE (N6,148) (I,TT(I), YY(I), I=1,NI)
```

```
* * * *
 140 FORMAT (I4, 2F12.3 )
 240 CONTINUE
     DO 280 J=1,NTT
     DO 260 K=1,NTT
 260 SXX(K,J) = 0.
     AA(J) = 0.
 280 SXY(J) = 0.
     NJ2 = NTT/2 + 1
     DO 360 I = 1,NI
     DO 320 J = 1,NTT
     FJ1 = FLOAT(J-1)
     FJ3 = FLOAT ( J-NJ2 )
     IF ( J.LE.NJ2 ) GO TO 300
     XX(J) = COS(FJ3*W*TT(I))
     GO TO 320
 300 XX(J) = SIN(FJ1*W*TT(I))
     IF( J.EQ.1 )XX(J) = 1.
 320 SXY(J) = SXY(J) +XX(J) *YY(I)
     DO 340 J = 1,NTT
     DO 340 K = 1,NTT
 340 SXX(K,J) = SXX(K,J) +XX(K) *XX(J)
 360 CONTINUE
     IT = 0
 380 IT = IT + 1
     DELMAX = 0.
     DO 420 K = 1,NTT
     SUM = 0.
     DO 400 J = 1,NTT
     IF (J.EQ.K) GO TO 400
     SUM = SUM -AA(J)*SXX(K,J)
 400 CONTINUE
     SUM = (SUM+SXY(K))/SXX(K,K)
     DEL = ABS(SUM-AA(K))
     IF (DEL.GT.DELMAX ) DELMAX = DEL
 420 AA(K) = SUM
     IF ( IT.GE.MAXIT ) GO TO 440
     IF (DELMAX.GT.DELTA ) GO TO 380
     GO TO 460
 440 WRITE(N6,150)
 150 FORMAT (69HCANNOT REACH DESIRED DELTA, INCREASE EITHER NI OR DELTA
    I AND TRY AGAIN)
     STOP 6666
 460 CONTINUE
     DO 470 KOEF=1,7
 470 TIDE(ITIDE,KOEF)=AA(KOEF)
     IF (NCHTID.NE.1) GO TO 540
     WRITE (N6,152)
 152 FORMAT (46H0        TIME     OBSERVED    COMPUTED       DIFF   )
     RES = 0.
     DO 520 I = 1,NI
     SUM = 0.
     DO 500 J = 2,NTT
     FJ1 = FLOAT ( J-1 )
     FJ3 = FLOAT ( J-NJ2 )
     IF ( J.LE.NJ2 ) GO TO 480
```

* * * *

```
      SUM = SUM +AA(J) *COS(FJ3*W*TT(I))
      GO TO 500                                                         TIDC 167
  480 SUM = SUM +AA(J) *SIN(FJ1*W*TT(I))                                TIDC 168
  500 CONTINUE                                                          TIDC 169
      SUM = SUM +AA(1)                                                  TIDC 170
      DIFF = SUM -YY(I)                                                 TIDC 171
      RES = RES + ABS(DIFF)                                             TIDC 172
  520 WRITE(N6,154) TT(I),YY(I),SUM,DIFF                                TIDC 173
  154 FORMAT ( 4F12.4 )                                                 TIDC 174
      WRITE (N6,156) RES                                                TIDC 175
  156 FORMAT (6HOTOTAL , 30X, F12.4 )                                   TIDC 176
  540 CONTINUE                                                          TIDC 177
C                                                                       TIDC 178
C                                                                       TIDC 179
C                                      CONSTANTS FOR INPUT WAVE FORM    TIDC 180
      WRITE(N6,158) JTIDE(ITIDE),(TIDE(ITIDE,I),I=1,7),PERIOD           TIDC 181
  158 FORMAT(///46H COEFFICIENTS FOR TIDAL INPUT WAVE AT JUNCTION16//85HTIDC 182
     1       A1          A2          A3          A4          A5          A6       TIDC 183
     2A7        PERIOD(HRS)//7F10.3,F12.2///31H WHERE THE WAVEFORM IS GIVETIDC 184
     3N BY//92H H(J) = A1 + A2.SIN(WT) + A3.SIN(2WT) + A4.SIN(3WT) + A5.TIDC 185
     4COS(WT) + A6.COS(2WT) + A7.COS(3WT))                              TIDC 186
      RETURN                                                            TIDC 187
      END                                                               TIDC 188
                                                                        TIDC 189
```

```
* * * *
      SUBROUTINE SWFLOW                                                 SWFL   1
C                                        HYDRODYNAMICS PROGRAM          SWFL   2
C                                        TIDAL OPTION                   SWFL   3
C                                                                       SWFL   4
C                                        SPECIFICATION STATEMENTS       SWFL   5
C                                                                       SWFL   6
      INTEGER CFRT
      REAL LEN,INTIME                                                   SWFL   8
C                                                                       SWFL   9
C                                        CONTROL                        SWFL  10
C                                                                       SWFL  11
      COMMON /CONTR/ N5,N6,N20,N21,  NTCYC,NQCYC,NHCYC,  NT,NOSWRT      SWFL  12
     1,  DELTQ,DELT,TZERO,    ISWCH(10)                                 SWFL  13
C                                                                       SWFL  14
C                                        GENERAL                        SWFL  15
C                                                                       SWFL  16
      COMMON  ALPHA(30),  NJ,NC,   ICYC,KCYC,NCYC,   WIND,WDIR,EVAP     SWFL  17
     1,  PRECP(50),NEXIT                                                SWFL  18
C                                                                       SWFL  19
C                                        JUNCTIONS                      SWFL  20
C                                                                       SWFL  21
      COMMON H(10), HN(10), HT(10), HBAR(10), HAVE(10), NCHAN(10,8),
     1       IPOINT(10,8), AS(10), VOL(10), X(10), Y(10), DEP(10),
     2       COF(10), QIN(10), QOU(10), QINST(10), QINBAR(10),
     3       QOUBAR(10)
C                                                                       SWFL  26
C                                        CHANNELS                       SWFL  27
C                                                                       SWFL  28
      COMMON LEN(10), NJUNC(10,2), B(10), R(10), A(10), AT(10), AK(10),
     1       W(10), QBAR(10), QAVE(10), V(10), VT(10), VBAR(10),
     2       FWIND(10), NUMCH(10), NTEMP(8), NCLOS(10), RBAR(10)
C                                                                       SWFL  33
C                                        PRINTOUT AND PLOTTING          SWFL  34
C                                                                       SWFL  35
      COMMON NPRT, IPRT, NHPRT, JPRT(10), PRTH(250,10), NQPRT, QPRT(10),
     1       PRTV(250,10), PRTQ(250,10), IDUM(12), ICOL(10), LTIME,
     2       NPLT, NPDEL, JPLT(10), HPLT(10)
C                                                                       SWFL  39
C                                        STAGE-TIME COEFFICIENTS        SWFL  40
C                                                                       SWFL  41
      COMMON YY(50) ,TT(50) ,EA(10),XX(10),SXX(10,10),SXY(10)           SWFL  42
     1,A1,A2,A3,A4,A5,A6,A7,PERIOD,JGW                                  SWFL  43
C                                                                       SWFL  44
C                                        STORMWATER                     SWFL  45
C                                                                       SWFL  46
      COMMON  TITLE(30),NJSW,JL(20,7),JSW(20)                           SWFL  47
     2, RAIN(100),INTIME(100),INRAIN,JROUND(20),JJRCON                  SWFL  48
C                                                                       SWFL  49
C                                           CONTROLLED OR FORCED NODES  SWFL  50
C                                                                       SWFL  51
      COMMON/HEADS/NTIDE,JTIDE(15),TIDE(15,7),NDAM,JDAM(50,2),          SWFL  52
     1DAM(50,3),DELH(50),SPILL(10),SPLBAR(10)                           SWFL  53
C                                                                       SWFL  54
C                                        TAPES                          SWFL  55
C                                                                       SWFL  56
```

```
* * * *
      COMMON /TAPES/ INCNT,IOUTCT,JIN(10),JOUT(10),NSCRAT(5)
      COMMON/ST2/ TITEL2(40)
C
      DIMENSION ENDER(2),VOLBAR(100)
      COMMON QT(50,2),ISW(50)
      DATA ENDER(1),ENDER(2)/4HENDQ,4HUANT/
C
C                                               TYPE DESIGNATIONS
C
C
C                                               INITIALIZATION
C
      N20 = NSCRAT(1)
      NEXIT=0
      DO 205 I=1,50
      DEP(I)=0.0
       AS(I)=0.
      QIN(I)=0.
      QOU(I)=0.
      DO 204 J=1,8
      IPOINT(I,J)=0
      NCHAN(I,J)=0
  204 CONTINUE
  205 CONTINUE
      DO 210 I=1,100
      FWIND(I) = 0.0
      Q(I)=0.0
      DO 209 J=1,2
      NJUNC(I,J)=0
  209 CONTINUE
  210 CONTINUE
C
C
C                                               SUBROUTINE INDATA CALLED TO
C                                               READ INPUT DATA
C
      CALL INDATA
C
C
C                                               FURTHER INITIALIZATION
C
      IOUTCT = IOUTCT + 1
      N21=JIN(INCNT)
      N22 = JOUT(IOUTCT)
      REWIND N22
      NTINT = 0
      TT(1) = 0.0
      TT(2) = 0.0
      NSTEPS = 0
      MUSW   = 0
      NQUAL = 0
      TOFLT = 0
      DO 220 I=1,10
  220 ICOL(I)=I
      DO 222 I=1,20
      ISW(I) = 0
      QT(I,1) = 0.0
      QT(I,2) = 0.0
```

* * * *

```
      QE(I,1) = 0.0
  222 QE(I,2) = 0.0
      TE=0.
      TEP=0.
      DELT2=DELT/2.0
      TZERO=TZERO*3600.0
      W=6.2832/(3600.*PERIOD)
      EVAP=EVAP/(1000.*30.*86400.)
      TOLD=0.
      KRAIN=1
      PREC = 0.0
      T=TZERO
  223 DO  224 I = 1,JHPRT
      MJPRT = JPRT(I)
      PRTH (1,I) = H(MJPRT)
  224 CONTINUE
      DO  225 I = 1,NQPRT
      MCPRT = CPRT(I)
      PRTQ(1,I) = Q(MCPRT)
      PRTV(1,I) = V(MCPRT)
  225 CONTINUE
C
C
C                                              READING OF INITIAL HYDROGRAPH
C                                              INFORMATION FROM INTERFACING
      IF(N21.EQ.0) GO TO 230
      REWIND N21
      READ (N21)          TITEL2
      WRITE (N6,7097)     TITEL2
 7097 FORMAT(1H1,20A4/(1H ,20A4))
      READ (N21)        NSTEPS,MJSW,NQUAL,TDELT,TZERO,TAREA
      WRITE (N6,7091) NSTEPS,MJSW,NQUAL,TDELT,TZERO,TAREA
 7091 FORMAT (3I10,3F10.2)
      READ(N21) (ISW(L),L=1,MJSW)
      WRITE(6,7092) (ISW(L),L=1,MJSW)
 7092 FORMAT(5I15)
      READ(N21) TT(1),(QT(L,1),NOUSE,(NOUSE,K=1,11),L=1,MJSW)
      TT(1) = TT(1) + TZERO
      WRITE(6,7093) TT(1),(QT(L,1),L=1,MJSW)
      READ(N21) TT(2),(QT(L,2),NOUSE,(NOUSE,K=1,11),L=1,MJSW)
      TT(2) = TT(2) + TZERO
      WRITE(6,7093) TT(2),(QT(L,2),L=1,MJSW)
      NINREC=2
      I1=1
      I2=2
      TTP=TZERO
  230 IF(NJSW.EQ.0) GO TO 235
      READ(N5,100) (JSW(L),L=1,NJSW)
      READ(N5,104) TE,(QE(L,2),L=1,NJSW)
      WRITE(N6,102) (JSW(L),L=1,NJSW)
      TEP=TE/3600.
      WRITE(N6,106) TEP,(QE(L,2),L=1,NJSW)
  100 FORMAT (16I5)
  102 FORMAT(28H1HYDROGRAPH INPUTS TO SYSTEM,//(6X,10I10))
  235 CONTINUE
```

```
* * * *
      TIME=TZERO
C
C
C                                          INITIAL TIME-STAGE RELATIONSHIP
C                                          COMPUTED
      IF(NTIDE.LE.0) GO TO 260
      DO 236 ITIDE=1,NTIDE
      JGW=JTIDE(ITIDE)
      A1=TIDE(ITIDE,1)
      A2=TIDE(ITIDE,2)
      A3=TIDE(ITIDE,3)
      A4=TIDE(ITIDE,4)
      A5=TIDE(ITIDE,5)
      A6=TIDE(ITIDE,6)
      A7=TIDE(ITIDE,7)
      H(JGW)=A1+A2*SIN(W*T)+A3*SIN(2.*W*T)+A4*SIN(3.*W*T)
     1         +A5*COS(W*T)+A6*COS(2.*W*T)+A7*COS(3.*W*T)
  236 CONTINUE
C
C
C                                          CHANNEL CONSTANTS COMPUTED
  260 DO 280 N=1,NC
      IF(NJUNC(N,1).LE.0)GO TO 280
      AK(N)=9.80621*2.2079*AK(N)**2/2.208196
      NL=NJUNC(N,1)
      NH=NJUNC(N,2)
      R(N)=R(N)+(H(NL)+H(NH))/2.
      A(N)=B(N)*R(N)
      IF (WIND.LE.0.0) GO TO 270
      FWIND(N)=-WIND**2*COS(WDIR/57.-ATAN2((X(NH)-X(NL)),(Y(NH)-Y(NL))))
     1 *3.029E-6
  270 CONTINUE
      AT(N)=A(N)
      QAVE(N)=0.
  280 CONTINUE
C
C
C                                          NODAL VOLUMES COMPUTED
      DO 340 J=1,NJ
      VOL(J)=0.
      IF(AS(J).EQ.0.) GO TO 340
      AREA=0.
      VOLUME=0.
      DO 300 K=1,8
      N=NCHAN(J,K)
      IF(N.LE.0) GO TO 320
      AREA=AREA+B(N)*LEN(N)
      VOLUME=VOLUME+B(N)*LEN(N)*R(N)
  300 CONTINUE
  320 DEPTH=VOLUME/AREA
      VOL(J)=DEPTH*AS(J)
  340 CONTINUE
C
C
C                                          START OF PROGRAM CORE, WITH
C                                          MAJOR HYDRAULIC COMPUTATIONS
```

```
* * * *
C
C
C                                                  START OF DAY DO LOOP, OUTER DO
C                                                  LOOP OF 3 NESTED DO LOOPS
      DO 1300 NT=1,NTCYC
      IF(NT.LT.NQSWRT) GO TO 350
      REWIND N22
      DO 345 J=1,NPLT
      I=IABS(JPLT(J))
  345 HPLT(J)=H(I)
      HOUR=TZERO/3600.
      WRITE(N22) HOUR,(HPLT(J),J=1,NPLT)
      NPTOT=1
  350 CONTINUE
      LTIME = 1
C
C
C                                                  START OF QUALITY DO LOOP
      DO 1240 NQ=1,NQCYC
C
C
C                                                  INITIALIZATION OF ARRAYS USED
C                                                  FOR HYDRAULIC OUTPUT TO BE USED
C                                                  BY THE SWQUAL SUBROUTINE
      IF (NT.LT.NQSWRT) GO TO 380
      DO 360 N=1,NC
      RBAR(N)=0.0
      VBAR(N)=0.
  360 QBAR(N)=0.
      DO 370 J=1,NJ
      HBAR(J)=0.
      QINBAR(J)=0.
      QOUBAR(J)=0.
      VOLBAR(J)=0.0
      SPLBAR(J)=0.0
  370 CONTINUE
  380 CONTINUE
C
C
C                                                  START OF HYDRAULIC DO LOOP,
C                                                  INNERMOST DO LOOP OF 3 NESTED
C                                                  DO LOOPS
      DO 1040 NHH=1,NHCYC
      IF(NT.LT.NQSWRT) GO TO 520
      TIME=TIME+DELT
C
C
C                                                  PRECIPITATION COMPUTATIONS FOR
C                                                  EACH TIME STEP
      PREC=0.
  390 IF(KRAIN-NRAIN) 395,410,410
  395 IF(TIME-INTIME(KRAIN+1)) 405,400,400
  400 PREC=PREC+RAIN(KRAIN)*(INTIME(KRAIN+1)-TOLD)/(1000.*3600.)
      KRAIN=KRAIN+1
      TOLD=INTIME(KRAIN)
```

```
* * * *
      GO TO 390
  405 PREC=(PREC+RAIN(KRAIN)*(TIME-TOLD)/(1000.*3600.))/DELT
      TOLD=TIME
  410 CONTINUE
      IF(N21.EQ.0) GO TO 445
      DO 418 L=1,MJSW
      J=ISW(L)
  418 QIN(J)=QINST(J)*DELT
  420 IF(TIME-TT(I2)) 435,425,425
  425 DO 430 L=1,MJSW
      J=ISW(L)
  430 QIN(J)=QIN(J)+QT(L,I1)*(TT(I2)-TTP)
      TTP=TT(I2)
      ITEMP=I2
      I2=I1
      I1=ITEMP
      IF(NINREC-NSTEPS) 431,432,432
  431 READ(N21) TT(I2),(QT(L,I2),NOUSE,(NOUSE,K=1,11),L=1,MJSW)
      TT(I2) = TT(I2) + TZERO
      NINREC=NINREC+1
 7093 FORMAT(4HIT= ,F10.1,3X,16HSOURCE FLOWS ARE,/(16X,6F15.3))
      WRITE(6,7093) TT(I2),(QT(L,I2),L=1,MJSW)
      GO TO 420
  432 TT(I2)=1000000.
      DO 433 L=1,MJSW
  433 QT(L,I2)=0.
      GO TO 420
  435 DO 440 L=1,MJSW
      J=ISW(L)
  440 QIN(J)=(QIN(J)+QT(L,I1)*(TIME-TTP))/DELT
      TTP=TIME
  445 CONTINUE
      IF(NJSW.EQ.0) GO TO 520
C
C
C                                       READ HYDROGRAPH INPUT OR AVERAGE
C                                       OR INTERPOLATE FOR TIME STEP
      IF(TIME.LE.TE) GO TO 480
      TEO=TE
      DO 460 L=1,NJSW
  460 QE(L,1)=QE(L,2)
C
C
C                                       READ HYDROGRAPHS
      READ (N5,104) TE,(QE(JJ,2),JJ=1,NJSW)
  104 FORMAT (8F10.0)
  470 CONTINUE
      TEP=TE/3600.
      WRITE(N6,106) TEP,(QE(L,2),L=1,NJSW)
  106 FORMAT(1H ,F7.2,10F10.1/(8X,10F10.1))
C
C
C                                       INTERPOLATE HYDROGRAPH
  480 DO 500 L=1,NJSW
      J=JSW(L)
```

```
* * * *
      SLOPE=(QE(L,2)-QE(L,1))/(TE-TEO)                                  SWFL 333
  500 QIN(J)=QINST(J)+QE(L,1)+SLOPE*(TIME-TEO)                          SWFL 334
  520 CONTINUE                                                          SWFL 335
C                                                                       SWFL 336
C                                        INITIALIZATION                 SWFL 337
C                                                                       SWFL 338
      T2=T+DELT2                                                        SWFL 339
      T=T+DELT                                                          SWFL 340
      DO 525 N=1,NC                                                     SWFL 341
      NCLOS(N)=0                                                        SWFL 342
      DO 525 M=1,2                                                      SWFL 343
  525 NJUNC(N,M)=IABS(NJUNC(N,M))                                       SWFL 344
      DO 530 J=1,NJ                                                     SWFL 345
      AS(J)=ABS(AS(J))                                                  SWFL 346
      DO 530 K=1,8                                                      SWFL 347
  530 NCHAN(J,K)=IABS(NCHAN(J,K))                                       SWFL 348
      NTIMS=0                                                           SWFL 349
C                                                                       SWFL 350
C                                        COMPUTATIONS OF VELOCITIES AT  SWFL 351
C                                        HALF TIME STEP, AND FLOWS AT   SWFL 352
C                                        QUARTER TIME STEP              SWFL 353
C                                                                       SWFL 354
  540 CONTINUE                                                          SWFL 355
      NDRY=0                                                            SWFL 356
      NTIMS=NTIMS+1                                                     SWFL 357
      DO 580 N=1,NC                                                     SWFL 358
      IF(NJUNC(N,1).LE.0)GO TO 580                                      SWFL 359
C                                                                       SWFL 360
C                                        DRY CHANNEL CHECK(UNDER 0.03M) SWFL 361
C                                                                       SWFL 362
      IF(R(N).GT.0.03) GO TO 560                                        SWFL 363
      VT(N)=0.0                                                         SWFL 364
      Q(N)=0.0                                                          SWFL 365
      GO TO 580                                                         SWFL 366
  560 CONTINUE                                                          SWFL 367
      NL=NJUNC(N,1)                                                     SWFL 368
      NH=NJUNC(N,2)                                                     SWFL 369
      DELV2=V(N)*(1.-AT(N)/A(N))                                        SWFL 370
     1 +DELT2*((V(N)**2*B(N)/A(N))-9.80621)*(H(NH)-H(NL))/LEN(N)        SWFL 371
     2+FWIND(N)/R(N)*DELT2                                              SWFL 372
      V2=V(N)+DELV2                                                     SWFL 373
      TEMP=DELT2*AK(N)/R(N)**1.3333333                                  SWFL 374
      DELV1=0.5*((1./TEMP+2.*ABS(V2))-                                  SWFL 375
     1SQRT((1./TEMP+ABS(2.*V2))**2-4.*V2**2))                           SWFL 376
      DELV1=-SIGN(DELV1,V2)                                             SWFL 377
      VT(N)=V(N)+DELV1+DELV2                                            SWFL 378
      Q(N)=VT(N)*A(N)                                                   SWFL 379
  580 CONTINUE                                                          SWFL 380
C                                                                       SWFL 381
C                                        COMPUTATION OF NODAL STAGE AT  SWFL 382
C                                        HALF TIME STEP                 SWFL 383
C                                                                       SWFL 384
      DO 590 J=1,100                                                    SWFL 385
      SPILL(J)=0.0                                                      SWFL 386
  590 CONTINUE                                                          SWFL 387
```

```
* * * *
      DO 660 J=1,NJ                                                     SWFL 388
      SUMQ=0.                                                           SWFL 399
      DO 620 K=1,8                                                      SWFL 390
      IF(NCHAN(J,K).LE.0) GO TO 620                                     SWFL 391
      N=NCHAN(J,K)                                                      SWFL 392
      IF(J.NE.NJUNC(N,1))GO TO 600                                      SWFL 393
      SUMQ=SUMQ+Q(N)                                                    SWFL 394
      GO TO 620                                                         SWFL 395
  600 SUMQ=SUMQ-Q(N)                                                    SWFL 396
  620 CONTINUE                                                          SWFL 397
  640 IF(AS(J).LE.0.) GO TO 660                                         SWFL 398
      SUMQ=QOU(J)-QIN(J)+(EVAP-PREC)*AS(J)-SPILL(J)+SUMQ                SWFL 399
      IF(NDAM.LE.0) GO TO 642                                           SWFL 400
      DO 641 IDAM=1,NDAM                                                SWFL 401
      KDAM=IDAM                                                         SWFL 402
      IF(J.EQ.JDAM(KDAM,1)) GO TO 650                                   SWFL 403
  641 CONTINUE                                                          SWFL 404
  642 HT(J)=H(J)-DELT2*SUMQ/AS(J)                                       SWFL 405
      IF(HT(J)+DEP(J).GT.0.) GO TO 660                                  SWFL 406
      HT(J)=-DEP(J)                                                     SWFL 407
      VOL(J)=0.                                                         SWFL 408
      AS(J)=-AS(J)                                                      SWFL 409
      DO 645 K=1,8                                                      SWFL 410
      NX=NCHAN(J,K)                                                     SWFL 411
      IF(NX.LE.0) GO TO 645                                             SWFL 412
      NCLOS(NX)=1                                                       SWFL 413
  645 CONTINUE                                                          SWFL 414
      NDRY=NDRY+1                                                       SWFL 415
      GO TO 660                                                         SWFL 416
  650 CONTINUE                                                          SWFL 417
      JDOWN=JDAM(KDAM,2)                                                SWFL 418
      DELHH(KDAM)=0.0                                                   SWFL 419
      WEIR1=DAM(KDAM,1)                                                 SWFL 420
      WEIR2=DAM(KDAM,2)                                                 SWFL 421
      WEIR3=DAM(KDAM,3)                                                 SWFL 422
      DO 655 ICT=1,3                                                    SWFL 423
      BASE=H(J)-WEIR2+DELHH(KDAM)/2.                                    SWFL 424
      IF(BASE) 651,651,652                                              SWFL 425
  651 SPILL(JDOWN)=0.0                                                  SWFL 426
      GO TO 653                                                         SWFL 427
  652 SPILL(JDOWN)=WEIR1*(BASE**WEIR3)                                  SWFL 428
  653 DELHH(KDAM)=DELT2/AS(J)*(-SUMQ-SPILL(JDOWN))                      SWFL 429
  655 CONTINUE                                                          SWFL 430
      HT(J)=H(J)+DELHH(KDAM)                                            SWFL 431
  660 CONTINUE                                                          SWFL 432
      IF(NDRY.EQ.0) GO TO 675                                           SWFL 433
      IF(NTIMS.GT.2) GO TO 675                                          SWFL 434
      DO 670 N=1,NC                                                     SWFL 435
      IF(NJUNC(N,1).LE.0) GO TO 670                                     SWFL 436
      IF(NCLOS(N).NE.1) GO TO 670                                       SWFL 437
      Q(N)=0.                                                           SWFL 438
      V(N)=0.                                                           SWFL 439
      DO 668 I=1,2                                                      SWFL 440
      II=NJUNC(N,I)                                                     SWFL 441
      DO 664 J=1,8                                                      SWFL 442
```

```
* * * *
      IF(NCHAN(II,J).EQ.N) GO TO 666
  664 CONTINUE
      GO TO 668
  666 NCHAN(II,J)=-N
  668 NJUNC(N,I)=-II
  670 CONTINUE
      GO TO 540
  675 CONTINUE
C
C                                            BOUNDARY STAGE CONDITION AT
C                                            HALF TIME STEP
C
      IF(NTIDE.LE.0) GO TO 677
      DO 676 ITIDE=1,NTIDE
      JGW=JTIDE(ITIDE)
      A1=TIDE(ITIDE,1)
      A2=TIDE(ITIDE,2)
      A3=TIDE(ITIDE,3)
      A4=TIDE(ITIDE,4)
      A5=TIDE(ITIDE,5)
      A6=TIDE(ITIDE,6)
      A7=TIDE(ITIDE,7)
      HT(JGW)=A1+A2*SIN(W*T2)+A3*SIN(2.*W*T2)+A4*SIN(3.*W*T2)
     1          +A5*COS(W*T2)+A6*COS(2.*W*T2)+A7*COS(3.*W*T2)
  676 CONTINUE
C
C                                            COMPUTATION OF CHANNEL CROSS-
C                                            SECTIONAL AREAS AT HALF TIME
C                                            STEP, FLOWS AT HALF TIME STEP,
C                                            AND VELOCITIES AT FULL TIME STEP
C
  677 DO 740 N=1,NC
      IF(NJUNC(N,1).LE.0)GO TO 740
      NL=NJUNC(N,1)
      NH=NJUNC(N,2)
      DELH=0.5*(HT(NH)-H(NH)+HT(NL)-H(NL))
      RNT=R(N)+DELH
      AT(N)=A(N)+B(N)*DELH
C
C                                            DRY CHANNEL CHECK(UNDER 0.03M)
C
      IF(RNT.GT.0.03) GO TO 680
      V(N)=0.
      Q(N)=0.
      GO TO 740
  680 CONTINUE
      DELV2=2.*VT(N)*(1.-A(N)/AT(N))
     1 +DELT*((VT(N)**2*B(N)/AT(N))-9.80621)*(HT(NH)-HT(NL))/LEN(N)
     1+FWIND(N)/RNT*DELT
      V2= V(N)+DELV2
      TEMP=DELT*AK(N)/RNT**1.3333333
      DELV1=0.5*((1./TEMP+2.*ABS(V2))-
     1SQRT((1./TEMP+2.*ABS(V2))**2-4.*V2**2))
      DELV1=-SIGN(DELV1,V2)
      V(N)=V(N)+DELV1+DELV2
```

```
* * * *
      Q(N)=0.5*(Q(N)+V(N)*AT(N))
  700 CONTINUE
C
C
C                                          CHANNEL FLOWS SUMMED
      IF (NT.LT.NQSWRT) GO TO 720
      QBAR(N)=QBAR(N)+Q(N)
      VBAR(N)=VBAR(N)+V(N)
      RBAR(N)=RBAR(N)+R(N)
  720 CONTINUE
C
C
C                                          EXCESSIVE VELOCITY CHECK
      IF(ABS(V(N)).LE.6.0) GO TO 740
      WRITE(6,108) NT,NQ,NHH,R(N),V(N),N
  108 FORMAT(27H0 V OVER 6 M/S, TIDAL CYCLE,I4,11H QUAL CYCLE,I4,
     112H HYDRO CYCLE,I4,6H DEPTH,E10.4,4H   V,E10.4,
     28H CHANNEL,I5)
      NEXIT=1
  740 CONTINUE
      IF (NEXIT.EQ.1) GO TO 1260
C
C
C                                          COMPUTATION OF NODAL STAGE AND
C                                          VOLUME AT FULL TIME STEP
      DO 750 J=1,100
      SPILL(J)=0.0
  750 CONTINUE
  760 DO 900 J=1,NJ
      SUMQ=0.
      HN(J)=-DEP(J)
      IF(AS(J).LE.0.) GO TO 900
      DO 800 K=1,8
      IF(NCHAN(J,K).LE.0) GO TO 800
      N=NCHAN(J,K)
      IF(J.NE.NJUNC(N,1))GO TO 780
      SUMQ=SUMQ+Q(N)
      GO TO 800
  780 SUMQ=SUMQ-Q(N)
  800 CONTINUE
      IF(NTIDE.LE.0) GO TO 8802
      DO 8801 ITIDE=1,NTIDE
      KTIDE=ITIDE
      IF(J.EQ.JTIDE(ITIDE)) GO TO 801
 8801 CONTINUE
 8802 IF(NDAM.LE.0) GO TO 820
      DO 8803 IDAM=1,NDAM
      KDAM=IDAM
      IF(J.EQ.JDAM(IDAM,1)) GO TO 802
 8803 CONTINUE
      GO TO 820
  801 JSW=J
      A1=TIDE(KTIDE,1)
      A2=TIDE(KTIDE,2)
      A3=TIDE(KTIDE,3)
```

```
* * * *
      A4=TIDE(KTIDE,4)
      A5=TIDE(KTIDE,5)
      A6=TIDE(KTIDE,6)
      A7=TIDE(KTIDE,7)
      HN(JGW)=A1+A2*SIN(W*T)+A3*SIN(2.*W*T)+A4*SIN(3.*W*T)
     1           +A5*COS(W*T)+A6*COS(2.*W*T)+A7*COS(3.*W*T)
      GO TO 814
  802 CONTINUE
      SUMQ=SUMQ+QOU(J)-QIN(J)+(EVAP-PREC)*AS(J)
      JDOWN=JDAM(KDAM,2)
      DELHH(KDAM)=DELHH(KDAM)*2.
      WEIR1=DAM(KDAM,1)
      WEIR2=DAM(KDAM,2)
      WEIR3=DAM(KDAM,3)
      DO 808 ICT=1,3
      BASE=H(J)-WEIR2+DELHH(KDAM)/2.
      IF(BASE) 803,803,804
  803 SPILL(JDOWN)=0.0
      GO TO 805
  804 SPILL(JDOWN)=WEIR1*(BASE**WEIR3)
  805 DELHH(KDAM)=DELT/AS(J)*(-SUMQ-SPILL(JDOWN))
  808 CONTINUE
      HN(J)=H(J)+DELHH(KDAM)
      VOL(J)=VOL(J)+DELHH(KDAM)*AS(J)
      GO TO 825
  814 CONTINUE
      DVOL=(HN(J)-H(J))*AS(J)
      QOU(J)=0.
      QIN(J)=(DVOL/DELT)+SUMQ
      IF(QIN(J).GT.0.) GO TO 815
      QOU(J)=-QIN(J)
      QIN(J)=0.
  815 VOL(J)=VOL(J)+DVOL
      GO TO 825
C
C
C                                      COMPUTATION OF 'ORDINARY' NODES
C                                      STAGE
  820 SUMQ=QOU(J)-QIN(J)+(EVAP-PREC)*AS(J)-SPILL(J)+SUMQ
      HN(J)=H(J)-DELT*SUMQ/AS(J)
C
  825 CONTINUE
  900 CONTINUE
C
C
C                                      NODAL VOLUMES AND FLOWS SUMMED
      IF (NT.LT.NCSWRT) GO TO 940
      DO 925 J=1,NJ
      HEAR(J)=HEAR(J)+HN(J)
      QINEAR(J)=QINEAR(J)+QIN(J)
      QOUEAR(J)=QOUEAR(J)+QOU(J)
      SPLEAR(J)=SPLEAR(J)+SPILL(J)
  925 CONTINUE
  940 CONTINUE
```

```
* * * *
C
C                                                         FULL TIME STEP COMPUTATION OF    SWFL 608
C                                                         HYDRAULIC RADIUS AND CHANNEL     SWFL 609
C                                                         CROSS-SECTIONAL AREAS            SWFL 610
  960 DO 980 N=1,NC                                                                        SWFL 611
      IF(NJUNC(N,1).EQ.0) GO TO 980                                                        SWFL 612
      NL=IABS(NJUNC(N,1))                                                                  SWFL 613
      NH=IABS(NJUNC(N,2))                                                                  SWFL 614
      DELH=0.5*(HN(NH)-H(NH)+HN(NL)-H(NL))                                                 SWFL 615
      R(N)=R(N)+DELH                                                                       SWFL 616
      A(N)=A(N)+B(N)*DELH                                                                  SWFL 617
  980 CONTINUE                                                                             SWFL 618
C                                                                                          SWFL 619
C                                                                                          SWFL 620
C                                                         COMPUTATION OF >ORDINARY>        SWFL 621
C                                                         NODE VOLUME                      SWFL 622
      DO 990 J=1,NJ                                                                        SWFL 623
      VOL(J)=0.0                                                                           SWFL 624
      IF(AS(J).EQ.0.0) GO TO 990                                                           SWFL 625
      AREA=0.0                                                                             SWFL 626
      VOLUME=0.0                                                                           SWFL 627
      DO 985 K=1,8                                                                         SWFL 628
      N=NCHAN(J,K)                                                                         SWFL 629
      IF(N.LE.0) GO TO 985                                                                 SWFL 630
      AREA=AREA+B(N)*LEN(N)                                                                SWFL 631
      VOLUME=VOLUME+B(N)*LEN(N)*R(N)                                                       SWFL 632
  985 CONTINUE                                                                             SWFL 633
      IF(VOLUME .EQ. 0.0) GO TO 986                                                        SWFL 634
      DEPTH=VOLUME/AREA                                                                    SWFL634A
      VOL(J)=DEPTH*AS(J)                                                                   SWFL 635
  986 VOLBAR(J)=VOLBAR(J)+VOL(J)                                                           SWFL 636
  990 CONTINUE                                                                             SWFL 637
C                                                                                          SWFL 638
C                                                                                          SWFL 639
C                                                         NODAL STAGE ARRAYS SHIFTED       SWFL 640
 1000 DO 1020 J=1,NJ                                                                       SWFL 641
 1020 H(J)=HN(J)                                                                           SWFL 642
      IF(NT.LT.NOSWRT) GO TO 1040                                                          SWFL 643
      IF(NPTOT.NE.NPDEL) GO TO 1030                                                        SWFL 644
      DO 1025 J=1,NPLT                                                                     SWFL 645
      I=IABS(JPLT(J))                                                                      SWFL 646
 1025 HPLT(J)=H(I)                                                                         SWFL 647
      HOUR=HOUR+DELT/3600.*FLOAT(NPDEL)                                                    SWFL 648
      WRITE(N22) HOUR,(HPLT(J),J=1,NPLT)                                                   SWFL 649
      NPTOT=0                                                                              SWFL 650
 1030 NPTOT=NPTOT+1                                                                        SWFL 651
C                                                                                          SWFL 652
C                                                                                          SWFL 653
C                                                         END OF HYDRAULIC OR INNER DO     SWFL 654
C                                                         LOOP                             SWFL 655
 1040 CONTINUE                                                                             SWFL 656
C                                                                                          SWFL 657
C                                                                                          SWFL 658
C                                                         AVERAGING OF FLOWS AND           SWFL 659
C                                                         VELOCITIES                       SWFL 660
                                                                                           SWFL 661
```

* * * *

```
      IF (NT.LT.NQSWRT) GO TO 1100
      DO 1060 N=1,NC
      IF(NJUNC(N,1).LE.0) GO TO 1060
      QBAR(N)=QBAR(N)/FLOAT(NHCYC)
      VBAR(N)=VBAR(N)/FLOAT(NHCYC)
      RBAR(N)=RBAR(N)/FLOAT(NHCYC)
      QAVE(N)=QAVE(N)+QBAR(N)/FLOAT(NQCYC)
 1060 CONTINUE
      DO 1080 J=1,NJ
      QINBAR(J)=QINBAR(J)/FLOAT(NHCYC)
      QOUBAR(J)=QOUBAR(J)/FLOAT(NHCYC)
      HBAR(J)=HBAR(J)/FLOAT(NHCYC)
      VOLBAR(J)=VOLBAR(J)/FLOAT(NHCYC)
      SPLBAR(J)=SPLBAR(J)/FLOAT(NHCYC)
      IF(QINBAR(J).EQ.0.) GOTO 1080
      IF(QOUBAR(J).EQ.0.) GOTO 1080
      QINBAR(J)=QINBAR(J)-QOUBAR(J)
      QOUBAR(J)=0.
      IF(QINBAR(J).GT.0.) GO TO 1080
      QOUBAR(J)=-QINBAR(J)
      QINBAR(J)=0.
 1080 CONTINUE
C
C                                           WRITE HYDRAULIC INFORMATION FOR
C                                           USE IN QUALITY PROGRAM
C
      WRITE(N20) NC,(QBAR(N),VBAR(N),RBAR(N),N=1,NC),
     1 (VOLBAR(J),QINBAR(J),QOUBAR(J),HBAR(J),SPLBAR(J),J=1,NJ)
C
C                                           STORE OUTPUT FOR SUBSEQUENT
C                                           PRINTOUT
C
 1100 IF (NT.EQ.(NQSWRT-1).AND.NQ.EQ.NQCYC) GO TO 1120
      GO TO 1180
 1120 DO 1140 I = 1,NHPRT
      MJPRT = JPRT(I)
      PRTH (1,I) = H(MJPRT)
 1140 CONTINUE
      DO 1160 I = 1,NQPRT
      MCPRT = CPRT(I)
      PRTQ(1,I) = Q(MCPRT)
      PRTV(1,I) = V(MCPRT)
 1160 CONTINUE
      GO TO 1240
 1180 IF(NT.LT.NQSWRT) GO TO 1240
      LTIME = LTIME + 1
C
C                                           STORE STAGE INFORMATION
C
      DO 1200 I=1,NHPRT
      MJPRT=JPRT(I)
 1200 PRTH(LTIME,I)=H(MJPRT)
C
C                                           STORE FLOWS AND VELOCITIES
C
```

```
* * * *
      DO 1220 I=1,NCPRT
      MCPRT=CPRT(I)
      PRTQ(LTIME,I)=Q(MCPRT)
 1220 PRTV(LTIME,I)=V(MCPRT)
C
C
C                                        END OF QUALITY DO LOOP
 1240 CONTINUE
      IF(ISWCH(1).NE.1) GO TO 1230
      IF (NT.NE.NQSWRT) GO TO 1280
 1260 CONTINUE
 1280 CONTINUE
C
C
C                                        SUBROUTINE PRTOUT CALLED FOR
C                                        HYDRAULIC INFORMATION PRINTOUT
C                                        FOR A ONE DAY CYCLE
      IF (NT.LT.NQSWRT) GO TO 1300
      CALL PRTOUT
C
C
C                                        END OF SUBROUTINE SWFLOW
 1300 CONTINUE
      END FILE N20
      REWIND N20
 1320 CONTINUE
      MCOUNT = 0
 1340 READ (N5,110) FINAL,CARD
  110 FORMAT (2A4)
      IF (FINAL.EQ.ENDER(1)) GO TO 1360
      MCOUNT = MCOUNT + 1
      IF (MCOUNT.GT.30) GO TO 1380
      GO TO 1340
 1360 IF (CARD.EQ.ENDER(2)) GO TO 1400
      MCOUNT = MCOUNT + 1
      IF (MCOUNT.GT.30) GO TO 1380
      GO TO 1340
 1380 WRITE (N6,112)
  112 FORMAT (62H0QUALITY PROGRAM HAS READ MORE THAN 30 CARDS AFTER COMP
     1PLETION)
      STOP 4444
 1400 WRITE (N6,114)
  114 FORMAT (33H0COMPLETION OF RECEIVING QUANTITY)
 1420 CONTINUE
C
C
C                                        RETURN TO SUBROUTINE RECEIV
      RETURN
      END
```

```
* * * *
      SUBROUTINE INDATA
C
C
C                                    INPUT DATA
C                                    HYDRODYNAMICS PROGRAM
C                                    SPECIFICATION STATEMENTS
C
      INTEGER CPRT
      REAL LEN, INTIME
C
C                                    CONTROL
C
      COMMON /CONTR/ N5,N6,N20,N21,  NTCYC,NJCYC,NHCYC,  NT,NOSWRT
     1, DELTC,DELT,TZERO,   ISWCH(10)
C
C                                    GENERAL
C
      COMMON  ALPHA(30),  NJ,NC,   ICYC,KCYC,NCYC,   WIND,WDIR,EVAP
     1, PRECP(50),NEXIT
C
C                                    JUNCTIONS
C
      COMMON H(10), AN(10), HT(10), HBAR(10), HAVE(10), NCHAN(10,8),
     1       IPOINT(10,8), AS(10), VOL(10), X(10), Y(10), DEP(10),
     2       COF(10), QIN(10), QOU(10), QINST(10), QINBAR(10),
     3       QOUBAR(10)
C
C                                    CHANNELS
C
      COMMON LEN(10), NJUNC(10,2), C(10), R(10), A(10), AT(10), AK(10),
     1       Q(10), QBAR(10), QAVE(10), V(10), VT(10), VBAR(10),
     2       FWIND(10), NUMCH(10), NTEMP(6), NCLOS(10), RBAR(10)
C
C                                    PRINTOUT AND PLOTTING
C
      COMMON NPRT, IPRT, NHPRT, JPRT(10), PRTH(250,10), NCPRT, CPRT(10),
     1       PRTV(250,10), PRTQ(250,10), IDUM(12), ICOL(10), LTIME,
     2       NPLT, NPDEL, JPLT(10), HPLT(10)
C
C                                    STAGE-TIME COEFFICIENTS
C
      COMMON YY(50) ,TT(50) ,AA(10),XX(10),SXX(10,10),SXY(10)
     1,A1,A2,A3,A4,A5,A6,A7,PERIOD,JGW
C
C                                    STORMWATER
C
      COMMON  TITLE(30),NJSW,QF(20,2),JSW(20)
     2, RAIN(100),INTIME(100),INRAIN,JBOUND(20),JJBOUN
C
C
C                                    CONTROLLED OR FORCED NODES
C
      COMMON/HEADS/NTIDE,JTIDE(15),TIDE(15,7),NDAM,JDAM(50,2),
     1JAM(50,3),DELHA(50),SPILL(100),SPLBAR(100)
C                                    TAPES
```

```
* * * *
      COMMON /TAPES/ INCNT,IOUTCT,JIN(10),JOUT(10),NSCRAT(5)
C
C                                          TYPE DESIGNATIONS
C
      DATA ASTERK,BLANK /4H****,4H    /
C
C
C                                          OPTION SWITCH, ISWCH(I)
C
C                                          ISWCH(1)
C                                          IF 1, WILL CALL TIDAL
C                                          COEFFICIENTS PROGRAM
C                                          ISWCH(2)
C                                          IF 1, SUPPRESSES CHANNEL AND
C                                          NODAL INFORMATION PRINT
C
C                                          STEP ONE
C                                          INITIALIZATION
      N5=5
      N6=6
C
      REWIND N20                           N20 ASSIGNED IN RECEIV
C
C
C                                          STEP TWO
C                                          TITLES, GENERAL CONTROL DATA,
C                                          AND JUNCTION AND CHANNEL INFOR-
C                                          MATION
C
C
C                                          READ TYPE A CARDS
C                                          (FIRST TWO CARDS CONTAIN HEAD-
C                                          INGS FOR HYDRODYNAMICS, SECOND
C                                          TWO CARDS CONTAIN HEADINGS
C                                          FOR IDENTIFICATION OF STORMWATER
C                                          INFORMATION)
      READ(N5,100) ALPHA
      READ(N5,100) TITLE
  100 FORMAT(15A4)
      WRITE(N6,102) ALPHA
  102 FORMAT (1H1, 15A4/ 1H , 15A4///)
C
C
C                                          READ TYPE B CARDS
C                                          SWITCH INFORMATION
      NTIDE=0
      NDAM=0
      READ(N5,104) NTIDE,NDAM,ISWCH(2)
  104 FORMAT(3I5)
C
C
C                                          READ TYPE C CARDS
C                                          CONTROL INFORMATION
      READ (N5,106) NTCYC,PERIOD,QINT,DELT,TZERO,NHPRT,NQPRT,NPLT,EVAP
     1,WIND,WDIR,NQSWRT,NJSW,INRAIN
```

* * * *

```
  106 FORMAT(I5,4F5.0,3I5,3F5.0,3I5)
      IPERID = PERIOD + 0.1
      IQINT=QINT*3600.+0.1
      IDELT = DELT + 0.1
      NQCYC=(IPERID *3600)/IQINT
      NHCYC = IQINT/IDELT
      NINT = (IPERID*3600)/IDELT
      NPDEL = (NINT+50)/100
C
C                                                READ TYPE D CARDS
C                                                PRECIPITATION IS READ AT THIS
C                                                POINT, RATE IS INCHES PER HOUR,
C                                                TIME IS READ IN MINUTES FROM
C                                                START OF STORM
C
      DO 210 N=1,100
      RAIN(N)=0.0
      INTIME(N)=0.0
  210 CONTINUE
      IF (INRAIN.EQ.0) GO TO 215
      READ(N5,110)(RAIN(I),INTIME(I),I=1,INRAIN)
  110 FORMAT (8F10.0)
  215 CONTINUE
      DELTQ=DELT*FLOAT(NHCYC)
      WRITE(N6,112) NTCYC
  112 FORMAT (15H0DAYS SIMULATED,I4)
      WRITE(N6,114) NQCYC
  114 FORMAT (29H0WATER QUALITY CYCLES PER DAY,I4)
      WRITE (N6,116) NHCYC
  116 FORMAT (43H0INTEGRATION CYCLES PER WATER QUALITY CYCLE,I4)
      WRITE (6,118) DELT
  118 FORMAT (30H0LENGTH OF INTEGRATION STEP IS,F6.0,8H SECONDS)
      WRITE (6,120) TZERO
  120 FORMAT (13H0INITIAL TIME,F6.2,6H HOURS)
      WRITE(N6,122)EVAP
  122 FORMAT(18H0EVAPORATION RATE,F5.1,13H MM PER MONTH)
      WRITE(N6,124)WIND,WDIR
  124 FORMAT(15H0WIND VELOCITY,F5.0,22H M/S    WIND DIRECTION,F5.0,19H DE
     1GREES FROM NORTH)
      WRITE (N6,128) NQSWR)
  128 FORMAT (26H0WRITE CYCLE STARTS AT THE,I4,11H TIME CYCLE//)
      IF (INRAIN.LE.0) GO TO 225
      WRITE (N6,130)
  130 FORMAT(75H0RAIN IN    MM   PER HOUR, AND TIME IN MINUTES, MEASURED
     1FROM START OF STORM/)
      WRITE (N6,131)
  131 FORMAT(15X,8H  MM/HR.,2X,8H MINUTES,4X,8H  MM/HR.,2X,8H MINUTES,
     14X,8H  MM/HR.,2X,8H MINUTES,4X,8H  MM/HR.,2X,8H MINUTES,4X,8H  MM/
     2HR.,2X,8H MINUTES/)
      DO 220 I = 1,100,5
      L = MIN0(I + 4,100)
      WRITE (N6,132) I, L, (RAIN(J),INTIME(J), J=I,L)
  132 FORMAT(I4,4H TO ,I3,10F11.3)
  220 CONTINUE
      DO 222 I=1,100
```

* * * *

```
  222 INTIME(I)=INTIME(I)*60.
      GO TO 230
  225 CONTINUE
      WRITE (N6,133)
  133 FORMAT (23HONO PRECIPITATION INPUT)
  230 CONTINUE
C
C                                                READ TYPE E CARDS
C                                                JUNCTION NUMBERS FOR DETAILED
C                                                PRINTOUT
C
      READ(N5,134)(JPRT(I),I=1,NHPRT)
  134 FORMAT(8I10)
      WRITE(N6,136)NHPRT,(JPRT(I),I=1,NHPRT)
  136 FORMAT (32HOPRINTED OUTPUT AT THE FOLLOWING,I3,10H JUNCTIONS,//
     1 (10X,16I6))
C
C                                                READ TYPE F CARDS
C                                                CHANNEL NUMBERS FOR DETAILED
C                                                PRINTOUT
C
      READ(N5,134)(CPRT(I),I=1,NQPRT)
      WRITE(N6,138)NQPRT,(CPRT(I),I=1,NQPRT)
  138 FORMAT(//15X,21HAND FOR THE FOLLOWINGI3,9H CHANNELS//(10X,8I10))
C
C                                                READ TYPE G CARDS
C                                                READ THE JUNCTION NUMBERS IF
C                                                PLOTS ARF REQUESTED, OTHERWISE
C                                                SKIP THIS READ
C
      IF (NPLT.NE.0) READ(N5,134) (JPLT(N),N=1,NPLT)
C
C                                                 CONTROLLED OR FORCED NODES
C
      IF(NTIDE.EQ.0) GO TO 560
      DO 550 ITIDE=1,NTIDE
      READ(N5,140) JTIDE(ITIDE),KO,NI,MAXIT,NCHTID
  140 FORMAT(5I5)
      READ (N5,142) (TT(I),YY(I),I=1,NI)
  142 FORMAT (8F10.0)
      CALL TIDCF(ITIDE,KO,NI,MAXIT,NCHTID)
  550 CONTINUE
  560 CONTINUE
      IF(NDAM.EQ.0) GO TO 580
      WRITE(N6,141)
  141 FORMAT(31H1DAM LOCATIONS AND COEFFICIENTS/4HONO.,3X,
     18HUPSTREAM,3X,10HDOWNSTREAM,2X,11HCOEFFICIENT,4X,6HHEIGHT,
     25X,8HEXPONENT/8X,5HJUNC.,7X,5HJUNC.//)
      DO 570 IDAM=1,NDAM
      READ(N5,143)JDAM(IDAM,1),JDAM(IDAM,2),DAM(IDAM,1),DAM(IDAM,2),
     1DAM(IDAM,3)
  143 FORMAT(2I5,3F10.0)
      WRITE(N6,145) IDAM,JDAM(IDAM,1),JDAM(IDAM,2),
     1DAM(IDAM,1),DAM(IDAM,2),DAM(IDAM,3)
  145 FORMAT(1H ,I3,6X,I5,9X,I3,6X,F10.4,2X,F10.4,2X,F10.4)
```

```
* * * *
  570 CONTINUE                                                          INDA 225
  580 CONTINUE                                                          INDA 226
      NJ=0                                                              INDA 227
      DO 150 J=1,50
      X(J)=0.0                                                          INDA 229
  150 Y(J)=0.0                                                          INDA 230
C                                                                       INDA 231
C                                         READ CARDS FOR                INDA 232
C                                         NODAL INFORMATION             INDA 233
C                                                                       INDA 234
      DO 620 I=1,50
      READ(N5,166) J,HEAD,SURF,QF1,QF2,DT,CF,X1,Y1                      INDA 236
  166 FORMAT(I5,F5.0,F10.0,2F5.0,2F10.0,20X,-3P2F5.0)                   INDA 237
      IF(J.GT.50) GO TO 640
      IF(J.GT.NJ)NJ=J                                                   INDA 239
      H(J)=HEAD                                                         INDA 240
      AS(J)=SURF                                                        INDA 241
      QIN(J)=QF1                                                        INDA 242
      QINST(J)=QF1                                                      INDA 243
      QOU(J)=QF2                                                        INDA 244
      X(J)=X1                                                           INDA 245
      Y(J)=Y1                                                           INDA 246
      DEP(J)=DT                                                         INDA 247
      COF(J)=CF                                                         INDA 248
  620 CONTINUE                                                          INDA 249
  640 CONTINUE                                                          INDA 250
      NC=0                                                              INDA 251
C                                                                       INDA 252
C                                         READ CARDS FOR                INDA 253
C                                         CHANNEL INFORMATION           INDA 254
C                                                                       INDA 255
      DO 660 I=1,100
      READ(N5,172)N,(NTEMP(K),K=1,4),ALEN,WIDTH,RAD,COEF,VEL            INDA 257
  172 FORMAT(5I5,5F10.0)                                                INDA 258
      IF (N.GT.225) GO TO 670                                           INDA 259
      IF(NTEMP(3).NE.0) GO TO 655                                       INDA 260
      NC=NC+1                                                           INDA 261
      N=NC                                                              INDA 262
      LEN(N)=ALEN                                                       INDA 263
      B(N)=WIDTH                                                        INDA 264
      A(N)=RAD*WIDTH                                                    INDA 265
      R(N)=RAD                                                          INDA 266
      AK(N)=COEF                                                        INDA 267
      V(N)=VEL                                                          INDA 268
      NJUNC(N,1)=MIN0(NTEMP(1),NTEMP(2))                                INDA 269
      NJUNC(N,2)=MAX0(NTEMP(1),NTEMP(2))                                INDA 270
      K=NJUNC(N,1)                                                      INDA 271
      DO 643 J=1,8                                                      INDA 272
      IF(IPOINT(K,J).EQ.NJUNC(N,2))GO TO 648                            INDA 273
      IF(IPOINT(K,J).EQ.0) GO TO 646                                    INDA 274
  643 CONTINUE                                                          INDA 275
  646 IPOINT(K,J)=NJUNC(N,2)                                            INDA 276
      NCHAN(K,J)=NC                                                     INDA 277
      GO TO 660                                                         INDA 278
  648 NC=NC-1                                                           INDA 279
```

* * * *

```
      M=NCHAN(K,J)
      LEN(M)=ALEN
      B(M)=B(M)+WIDTH
      R(M)=RAD
      A(M)=R(M)*B(M)
      AK(M)=COEF
      V(M)=VEL
      GO TO 660
  655 CALL TRIAN(NTEMP(1),NTEMP(2),NTEMP(3),NTEMP(4))
  660 CONTINUE
  670 CONTINUE
      IF (ISWCH(2).EQ.1) GO TO 674
      WRITE(N6,170)
  170 FORMAT(110H1CHANNEL   LENGTH   WIDTH     AREA    MANNING   VELOCIT
     1Y   BOTTOM ELEV              JUNCTIONS AT ENDS    MAX INT /     70H
     2 NUMBER       (M)       (M)      (SQ M)   COEF.    (M/S)     (M - POS
     3 DN)/)
  674 CONTINUE
      DO 695 N=1,NC
      IF (AK(N).LE.0.0) AK(N)=0.018
      IF(B(N).GT.0.) GO TO 683
      K=NJUNC(N,1)
      NJUNC(N,1)=0
      DO 682 J=1,8
      IF(IPOINT(K,J).EQ.0) GO TO 682
      IF(IPOINT(K,J).NE.NJUNC(N,2)) GO TO 681
      WRITE(N6,168) N,K,NJUNC(N,2)
  168 FORMAT (8H CHANNEL,I4,8H JOINING,I4,4H AND,I4,38H DELETED DUE TO Z
     1ERO OR NEGATIVE WIDTH)
      NCHAN(K,J)=0
      IPOINT(K,J)=0
      NJUNC(N,2)=0
      GO TO 695
  681 CONTINUE
  682 CONTINUE
  683 CONTINUE
      K=NJUNC(N,2)
      DO 684 J=1,8
      IF(IPOINT(K,J).EQ.NJUNC(N,1)) GO TO 687
      IF(IPOINT(K,J).EQ.0) GO TO 685
  684 CONTINUE
  685 CONTINUE
      IPOINT(K,J)=NJUNC(N,1)
      NCHAN(K,J)=N
  687 CONTINUE
      NUMCH(N)=NJUNC(N,2)+NJUNC(N,1)*1000
      DO 688 J=1,NOPRT
      IF(CPRT(J).NE.NUMCH(N)) GO TO 688
      CPRT(J)=N
      GO TO 690
  688 CONTINUE
  690 CONTINUE
      NJ1=NJUNC(N,1)
      NJ2=NJUNC(N,2)
      TF=B(N)+0.5*(H(NJ1)+H(NJ2))
```

```
* * * *
      IF(TF.GT.0.0) TF=0.75*LEN(N)/SQRT(9.8*TF)
      XMK=BLANK
      IF(TF.LT.DELT) XMK=ASTERK
      IF(ISWCH(2).EQ.1) GO TO 695
      WRITE(N6,174)  N,LEN(N),B(N),A(N),AK(N),V(N),R(N),(NJUNC(N,K),
     1 K=1,2),TF,XMK
  174 FORMAT(I5,F11.0,F6.0,-3PF10.0,0PF9.3,F10.2,F13.1,I19,I6,F16.0,1X,
     1A4)
  695 CONTINUE
      IF (ISWCH(2).EQ.1) GO TO 698
      WRITE(N6,182)
  182 FORMAT(124H1JUNCTION   INITIAL HEAD   SURFACE AREA    INPUT    OUT
     1PUT            CHANNELS ENTERING JUNCTION                  COORDINA
     2TES/122H  NUMBER          (M)          ( SQ M )    (CU M/S)  (CU M/S
     3)                                                  X        Y/)
      ATOT=0.
      DO 696 J=1,NJ
      ATOT=ATOT+AS(J)
      WRITE(N6,184) J,H(J),AS(J),QIN(J),QOU(J),(NCHAN(J,K),K=1,8),
     1 X(J),Y(J)
  184 FORMAT(I7,F13.2,F15.2,2F10.2,I10,7I6,F10.1,F7.1)
  696 CONTINUE
      WRITE(6,190) ATOT
  190 FORMAT(E20.6)
  698 CONTINUE
      WRITE (N6,192) TITLE
  192 FORMAT (1H015A4,15A4)
C
C                                         STORE SYSTEM DATA ON QUALITY
C                                         OUTPUT TAPE
C
      WRITE (N20) TITLE,ALPHA,NJ,NC,NOCYC,DELTQ,((NCHAN(J,K),K=1,8),
     1 AS(J),DEP(J),J=1,NJ),(LEN(N),(NJUNC(N,K),K=1,2),N=1,NC),
     2 NTIDE,(JTIDE(M),M=1,NTIDE),NDAM,((JDAM(M,N),N=1,2),M=1,NDAM)
      RETURN
      END
```

```
* * * *
      SUBROUTINE PRTOUT
C
C                                      PRINTING OUTPUT ROUTINE
C
C                                      HYDRODYNAMICS PROGRAM
C                                      SPECIFICATION STATEMENTS
C
C
C                                      CONTROL
C
      COMMON /CONTR/ N5,N6,N20,N21,  NTCYC,NQCYC,NHCYC,  NT,NQSWRT
     1,  DELTQ,DELT,TZERO,   ISWCH(10)
C
C                                      GENERAL
C
      COMMON  ALPHA(30),  NJ,NC,   ICYC,KCYC,NCYC,   WIND,WDIR,EVAP
     1,  PRECP(50),NEXIT
C
C                                      JUNCTIONS
C
      COMMON H(10), HN(10), HT(10), HBAR(10), HAVE(10), NCHAN(10,8),
     1       IPOINT(10,8), AS(10), VOL(10), X(10), Y(10), DEP(10),
     2       COF(10), QIN(10), QOU(10), QINST(10), CINBAR(10),
     3       COUBAR(10)
C
C                                      CHANNELS
C
      COMMON LEN(10), NJUNC(10,2), B(10), R(10), A(10), AT(10), AK(10),
     1       Q(10), QBAR(10), QAVE(10), V(10), VT(10), VBAR(10),
     2       FWIND(10), NUMCH(10), NTEMP(8), NCLOS(10), RBAR(10)
C
C                                      PRINTOUT AND PLOTTING
C
      COMMON NPRT, IPRT, NHPRT, JPRT(10), PRTH(250,10), NQPRT, CPRT(10),
     1       PRTV(250,10), PRTQ(250,10), IDUM(12), ICOL(10), LTIME,
     2       NPLT, NPDEL, JPLT(10), HPLT(10)
C
C                                      STAGE-TIME COEFFICIENTS
C
      COMMON YY(50) ,TT(50) ,AA(10),XX(10),SXX(10,10),SXY(10)
     1,A1,A2,A3,A4,A5,A6,A7,PERIOD,JGW
C
C                                      STORMWATER
C
      COMMON  TITLE(30),NJSW,QE(20,2),JSW(20)
     2, RAIN(100),INTIME(100),IRAIN,JBOUND(20),JJBOUN
C
C                                      TAPES
C
      COMMON /TAPES/ INCNT,IOUTCT,JIN(10),JOUT(10),NSCRAT(5)
C
C                                      TYPE DESIGNATIONS
C
      INTEGER CPRT
      REAL LEN
```

```
* * * *
  100 FORMAT (1H1, 15A4/ 1H , 15A4///)
      DO 220 I=1,NHPRT,6
      WRITE (6,100) ALPHA
      WRITE (N6,102) TITLE
  102 FORMAT(1H0,30A4)
      WRITE (N6,104) NT
  104 FORMAT (7H0DAY IS,I4)
      WRITE (6,106)
  106 FORMAT (125H0 * * * * * * * * * * * * * * * * * * * * * *   T I M E
     1H I S T O R Y   O F   S T A G E   * * * * * * * * * * * * * * * * * *
     2* * *)
      WRITE(6,108) JPRT(I),JPRT(I+1),JPRT(I+2),JPRT(I+3),JPRT(I+4),
     1 JPRT(I+5)
  108 FORMAT (1H0,23X,9H JUNCTION,I5,13H      JUNCTION,I5,13H      JUNCTIO
     1N,I5,13H      JUNCTION,I5,13H      JUNCTION,I5,13H      JUNCTION
     2,I5/12H      HOUR,14X,100H   HEAD(M)              HEAD(M)
     3 HEAD(M)             HEAD(M)             HEAD(M)            HEAD(M)/)
      T=TZERO-DELT*FLOAT(NHCYC)
      LT=MIN0(I+5,NHPRT)
      DO 220 L=1,LTIME
      T=T+DELT*FLOAT(NHCYC)
      HOUR=T/3600.
  220 WRITE(6,110) HOUR,(PRTH(L,K),K=I,LT)
  110 FORMAT(1H ,F11.2,9X,F14.2,5F18.2)
C
C                                  PRINT FLOWS AND VELOCITIES
C
      DO 240 I=1,NQPRT,6
      WRITE (6,100) ALPHA
      WRITE (N6,102) TITLE
      WRITE (N6,104) NT
      WRITE (6,112)
  112 FORMAT (125H0 * * * * * * * * * * * * * * * * *   T I M E   H I S T O R
     1 Y   O F   F L O W   A N D   V E L O C I T Y   * * * * * * * * * * * * *
     2* * *)
      DO 230 IC=1,6
      JC=I-1+IC
      NX=CPRT(JC)
      IF(JC.GT.NQPRT)  NX=CPRT(NQPRT)
      IDUM(2*IC-1)= IABS(NJUNC(NX,1))
      IDUM(2*IC)   = IABS(NJUNC(NX,2))
  230 CONTINUE
      WRITE(6,114) (IDUM(IC),IC=1,12)
  114 FORMAT(1H0,18X,6(10H    CHANNEL,I3,I4)/
     2,6X,114H HOUR                  FLOW  VEL.        FLOW  VEL.        FLOW
     3 VEL.        FLOW  VEL.        FLOW  VEL.        FLOW  VEL.,/,24X
     4 , 96HCU M/S  M/S        CU M/S  M/S        CU M/S  M/S        CU M/S  M
     5/S        CU M/S  M/S        CU M/S  M/S,/)
      T=TZERO-DELT*FLOAT(NHCYC)
      LT=MIN0(I+5,NQPRT)
      DO 240 L=1,LTIME
      T=T+DELT*FLOAT(NHCYC)
      HOUR=T/3600.
  240 WRITE(6,116) HOUR,(PRTQ(L,K),PRTV(L,K),K=I,LT)
  116 FORMAT(1H ,F10.2,8X,6(F10.2,F7.3))
```

* * * *

```
      IF (NEXIT.EQ.1) STOP 3333
      DO 260 I = 1,NHPRT
      PRTH(1,I) = PRTH(LTIME,I)
  260 CONTINUE
      DO 280 I = 1,NJPRT
      PRTQ(1,I) = PRTQ(LTIME,I)
      PRTV(1,I) = PRTV(LTIME,I)
  280 CONTINUE
      NTINT=1
      IF(NJSW.GT.0)
     1WRITE(N6,118) (JSW(L),L=1,NJSW)
  118 FORMAT(33H1HYDROGRAPH INPUT NODES TO SYSTEM,//(6X,10I10))
      RETURN
      END
```

```
* * * *
      PROGRAM QUALT
C
C                                                 BASIN MODEL TEST PROGRAM
C
C
C                                                 COMMON BLOCKS TO ZERO ARRAYS
C
      COMMON          IZZZ(9285)
C
C                                                 TAPE FILES
C
      COMMON/TAPES/INCNT,IOUTCT,JIN(10),JOUT(10),NSCRAT(5)
      INTEGER RUN
C
C                                                 ZERO ARRAYS
C
      DO 300 I=1,9265
  300 IZZZ(I)=0
C
C                                                 SETUP TAPE FILES
C
      N5=5
      N6=6
      INCNT=0
      IOUTCT=0
      JIN(1) = 23
      JOUT(1) = 24
      NSCRAT(1) = 25
      NSCRAT(2) = 26
      NSCRAT(3) = 27
      NSCRAT(4) = 28
    2 CALL REQUAL
      STOP 1111
      END
```

```
* * * *
      SUBROUTINE LOOPQL
C
C                                      QUALITY CYCLE LOOP
C
C
C                                      SPECIFICATION STATEMENTS
C
      REAL MADD,LEN
      DIMENSION TT(2),QWITH(100),WITH(100,2),SUMQ(100),CONST(4)
     1 ,QADD(100),ADD(100,2),IFLG(15)
C
C                                      GENERAL AND CONTROL
C
      COMMON /TAPES/ INCNT,IOUTCT,JIN(10),JOUT(10),NSCRAT(5)
C
C                                      BLANK COMMON
C
      COMMON JGW,NTC,NOCYC,DELTQ,QE,QF,ALPHA(30),TITLSW(30),ICOL(10)
     1 ,ISWCH(10),XR(11),XML(15,11),XMF(11),XMEO(15,11)
     2 ,N5,N6,N10,N20,N30,N40,NSTART,XRQU(15,11)
C
C                                      JUNCTIONS
C
      COMMON NJ, NCHAN(50,8), QIN(50), QOU(50), VOL(50), VOLO(50),
     X       AS(50)
C
C                                      CHANNELS
C
      COMMON NC, NJUNC(100,2), Q(100), LEN(100), U(100)
C
C                                      SOURCE DATA
C
      COMMON NJSW,JSW(20)
     1,MJSW,ISW(100),CT(11,100,2),INSTM
C
C                                      QUALITY
C
      COMMON KCON, C2(11), CS(15,11), ICON(11), C(50,11), SUMC(50,11),
     1       CMAX(50,11), CMIN(50,11), MADD(50,11), DCDT(50,11),
     2       CE(11,50,2), TE(11), TEP(11), SLOPE(20), CSPIN(50,11),
     3       TEC(11)
C
C                                      PRINTING
C
      COMMON NQPRT,ITCPRT,LOCPRT,NSTPRT,NOCT01,ISKIP,MSTPRT,NPRT,KPRT
C
C                                      LINKAGE AND DECAY COEFFICIENTS
C
      COMMON /DECAY/ MAP(13), MODCHL, MODNIT, MCOP, MODO2, MODBOD,
     1               MODCOL, MODMET, SUNRIS, SUNSET, AVGLIT, EXCOEF,
     2               TEMP(50), GRAZE(50), RRESP, GTCOEF, COEF(50,8),
     3               CONSTN, CONSTP, AZINCH, PINCH, O2INCH, BENTH(50),
     4               SATLIT, THETA(8), RAMM(50), RTFITE(50), RTRATE(50),
     5               RP(50), REAER(50), DEOXY(50), RCOLIF(50),
     6               RMETAL(50), A(100), B(100), CCHAN(100), MAPBCK(13)
```

* * * *

```
C
C                                          DAM DATA
C
      COMMON /DAM/ NDAM,JDAM(50,2),SPILL(100)
C
C                                          TIDAL JUNCTION DATA
C
      COMMON /TIDAL/ NTIDE,JTIDE(15)
C
C                                          PHYSICAL DATA
C
      COMMON /PHYS/ DEP(50), ELEV(50), R(100)
C
C                                          TITLING
C
      COMMON /LBL/ COUT(12,4)
      COMMON /ST1/ TITLE(40)
C
C
C
C
      IF(INSTM.GE.1) GO TO 10
      DO 4 II=1,15
      IFLG(II)=0
    4 CONTINUE
      DO 5 J=1,NJ
      QWITH(J)=0.0
      QADD(J)=0.0
    5 CONTINUE
   10 IF(INSTM.NE.0) GO TO 190
      N21=JIN(INCNT)
      IF(N21.EQ.0) GO TO 190
      REWIND N21
      READ (N21) TITEL
      WRITE (6,7093) TITEL
 7093 FORMAT(1H1,20A4/1H ,20A4)
      READ(N21) NSTEPS,MJSW,NCON ,TDELT,TZERO,TAREA
      TZ=TZERO/3600.
      WRITE(6,7091) NSTEPS,MJSW,NCON,TDELT,TZ,TAREA
 7091 FORMAT(34H0 DATA TRANSMITTED FROM INPUT FILE/
     129H NUMBER OF STEPS               =,I5/
     229H NUMBER OF INPUT POINTS        =,I5/
     329H NUMBER OF CONSTITUENTS        =,I5/
     429H TIME INCREMENT                =,F8.0,5H SECS/
     529H INITIAL TIME                  =F10.2,4H HRS/
     629H TOTAL AREA                    =,F10.2,14H SQ KILOMETERS)
      READ(N21) (ISW(L),L=1,MJSW)
      WRITE (6,6501) (ISW(L),L=1,MJSW)
 6501 FORMAT(30H0INPUT POINTS ARE LISTED BELOW,/
     1(10X,10I10))
      READ(N21) TT(1),(ADD(L,1),WITH(L,1),(CT(K,L,1),K=1,11)
     1 ,L=1,MJSW)
      TT(1) = TT(1) + TZERO
      TH=TT(1)/3600.
      WRITE(6,6503)
```

```
* * * *
 6503 FORMAT(34H1TOTAL SOURCE LOADS FROM DATA FILE/
     1      5CHOTIME     JUNCTION SULFATES TOTAL FE MANGANESE,
     2      5CH                           ALUMINUM             ,
     3      3CH            TDS     TSS                         ,
     4      5CH HOURS            GM/SEC    GM/SEC   GM/SEC     ,
     5      5CH                            GM/SEC              ,
     6      3CH           GM/SEC   GM/SEC                      )
      WRITE(6,6502) (TH,ISW(L),(CT(K,L,1),K=1,NCON),L=1,MJSW)
 6502 FORMAT(1H ,F5.2,I9,1X,11F10.3)
      READ(N21) TT(2),(ADD(L,2),WITH(L,2),(CT(K,L,2),K=1,11)
     1 ,L=1,MJSW)
      TT(2) = TT(2) + TZERO
      TH=TT(2)/3600.
      WRITE(6,6502) (TH,ISW(L),(CT(K,L,2),K=1,NCON),L=1,MJSW)
      NINREC=2
      I1=1
      I2=2
      TIME=TZERO
      TTP=TIME
  190 CONTINUE
C                                     MAIN LOOP
C
      DO 548 ICYC=1,NQCYC
      MSTART=ICYC
C
C                                     READ HYDRAULIC INFORMATION FROM
C                                     FAST DRUM(DISC)
C
      READ(N10) NQ,(Q(N),U(N),R(N),N=1,NC),(VOL(J),QIN(J),QOU(J),
     1ELEV(J),SPILL(J),J=1,NJ)
      DO 200 J=1,NJ
      IF(QIN(J).LT.0.) QIN(J)=0.
  200 CONTINUE
C
C
C                                     VARIABLE FLOW INTERPOLATION
C                                     OR AVERAGING
C
      TIME=TIME+DELTQ
      IF(N21.EQ.0) GO TO 2050
      DO 2010 L=1,MJSW
      J=ISW(L)
      QWITH(J)=0.0
      QADD(J)=0.0
      DO 2010 K=1,KCON
 2010 MADD(J,K)=CSPIN(J,K)*DELTQ
 2012 IF(TIME-TT(I2)) 2040,2015,2015
 2015 DO 2020 L=1,MJSW
      J=ISW(L)
      QWITH(J)=QWITH(J)+WITH(L,I1)*(TT(I2)-TTP)
      QADD(J)=QADD(J)+ADD(L,I1)*(TT(I2)-TTP)
      DO 2020 K=1,KCON
      KK=MAPBCK(K)
 2020 MADD(J,K)=MADD(J,K)+CT(KK,L,I1)*(TT(I2)-TTP)
      TTP=TT(I2)
```

```
* * * *
      ITEMP=I2
      I2=I1
      I1=ITEMP
      IF(NINREC-NSTEPS) 2025,2030,2030
 2025 READ(N21) TT(I2),(ADD(L,I2),WITH(L,I2),(CT(K,L,I2),K=1,11)
    1 ,L=1,MJSW)
      TT(I2) = TT(I2) + TZERO
      TH=TT(I2)/3600.
      WRITE(6,6503)
      WRITE(6,6502) (TH,ISW(L),(CT(K,L,I2),K=1,NCON),L=1,MJSW)
      NINREC=NINREC+1
      GO TO 2012
 2030 TT(I2)=TT(I1)+TT(I1)-TT(I2)
      DO 2035 L=1,MJSW
      DO 2035 K=1,NCON
 2035 CT(K,L,I2)=0.
      GO TO 2012
 2040 DO 2045 L=1,MJSW
      J=ISW(L)
      QWITH(J)=(QWITH(J)+WITH(L,I1)*(TIME-TTP))/DELTQ
      QADD(J)=(QADD(J)+ADD(L,I1)*(TIME-TTP))/DELTQ
      DO 2045 K=1,KCON
      KK=MAPBCK(K)
 2045 MADD(J,K)=(MADD(J,K)+CT(KK,L,I1)*(TIME-TTP))/DELTQ
      TTP=TIME
 2050 IF(NJSW.EQ.0) GO TO 4470
      DO 4400 K=1,KCON
      IF (TIME.LE.TE(K)) GO TO 4400
      TEO(K) = TE(K)
      DO 4440 L =1,NJSW
      CE(K,L,1) = CE(K,L,2)
 4440 CONTINUE
C
C                                          READ TIME AND LOADING RATE
C
      READ(N5,4320) (CONST(I),I=1,4),TE(K),(CE(K,L,2),L=1,NJSW)
 4320 FORMAT(4A4,F10.0,9F6.0,/,11F6.0)
      TEP(K) = TE(K)/3600.
      WRITE(N6,4380) (CONST(I),I=1,4),TEP(K)
 4380 FORMAT(1H0,10X,23H ADDITIONAL SOURCES OF ,4A4,4H AT ,F5.2,
     1 17H HOURS FROM START,/,1H0,10X,
     2 120HJUNCTION MASS RATE  JUNCTION MASS RATE  JUNCTION MASS RATE  J
     3UNCTION MASS RATE  JUNCTION MASS RATE JUNCTION MASS RATE   ,/,1H0)
      WRITE (N6,4340)( JSW(L), CE(K,L,2),L=1,NJSW)
 4340 FORMAT(1H ,6(I5,F11.2))
 4400 CONTINUE
      DO 4460 K=1,KCON
      DO 4460 L =1,NJSW
      J = JSW(L)
      SLOPE(L)=(CE(K,L,2)-CE(K,L,1))/(TE(K)-TEO(K))
      MADD(J,K)=CSPIN(J,K)+(CE(K,L,1)+SLOPE(L)*(TIME-TEO(K)))
 4460 CONTINUE
 4470 CONTINUE
C
C
```

```
* * * *
C                                          SET BOUNDARY CONCENTRATION
C                                          CONDITIONS
C
      IF(NTIDE.LE.0) GO TO 236
      DO 235 ITIDE=1,NTIDE
      JGW=JTIDE(ITIDE)
      DO 230 KC=1,KCON
      IF(IFLG(ITIDE)-1) 208,210,220
  208 DO 209 KCC=1,KCON
      XME(ITIDE,KCC)=1.
  209 XMEO(ITIDE,KCC)=0.
  210 IF(QIN(JGW)) 211,211,215
  211 IF(QOU(JGW)) 215,215,221
  215 IFLG(ITIDE)=1
  218 MADD(JGW,KC)=(XRQD(ITIDE,KC)/XME(ITIDE,KC)*XMEO(ITIDE,KC)
     1   +CS(ITIDE,KC)-C(JGW,KC))*QIN(JGW)
      GO TO 230
  220 IF(QOU(JGW)) 215,215,227
  221 IFLG(ITIDE)=2
      DO 223 KCC=1,KCON
      XME(ITIDE,KCC)=1.
  223 XMEO(ITIDE,KCC)=0.
  227 XME(ITIDE,KC)=XME(ITIDE,KC)+QOU(JGW)
      XMEO(ITIDE,KC)=XMEO(ITIDE,KC)+QOU(JGW)*(C(JGW,KC)-CS(ITIDE,KC))
      MADD(JGW,KC)=0.0
  230 CONTINUE
  235 CONTINUE
  236 CONTINUE
C
C
C                                          COMPUTE CONCENTRATION CHANGES
C
      DO 265 J=1,NJ
      IF(NCHAN(J,1).EQ.0) GO TO 265
      SUMQ(J)=0.0
      DO 245 KC=1,KCON
  245 DCDT(J,KC)=0.
C
C
C                                          ADVECTIVE MOVEMENT IN CHANNELS
C
      DO 260 K=1,8
      N=NCHAN(J,K)
      IF(N.EQ.0) GO TO 260
      JL=NJUNC(N,1)
      JH=NJUNC(N,2)
      IF((J.EQ.JL).AND.(Q(N).GE.0.)) GO TO 260
      IF((J.EQ.JH).AND.(Q(N).LE.0.)) GO TO 260
      SUMQ(J)=SUMQ(J)+ABS(Q(N))
      DO 250 KC=1,KCON
      DCDT(J,KC)=DCDT(J,KC)+Q(N)*(C(JL,KC)-C(JH,KC))
  250 CONTINUE
  260 CONTINUE
  265 CONTINUE
      IF (NDAM.NE.0)   CALL DAMS(SUMQ)
```

* * * *

```
C
C                                      SOURCE CONTRIBUTION
C                                      UPDATE CONCENTRATION AND CHECK
C                                      DEPLETION
C
      DO 280 J=1,NJ
      IF(NCHAN(J,1).EQ.0) GO TO 280
      IF(VOL(J).EQ.0.0) GO TO 280
      DO 270 KC=1,KCON
      C(J,KC)=C(J,KC)+(DCDT(J,KC)+MADD(J,KC)-C(J,KC)
     1                 *(QADD(J)+QWITH(J)))/VOL(J)*DELTQ
      IF(C(J,KC).LT.0.0) C(J,KC)=0.0
  270 CONTINUE
  280 CONTINUE
C
C                                      DECAY AND REAERATION
C
      IF(ISWCH(4).NE.1) GO TO 300
      CALL ADJUST
      DO 295 J=1,NJ
      IF(NCHAN(J,1).EQ.0) GO TO 295
      CALL LINK(TIME,J)
  295 CONTINUE
  300 CONTINUE
C
C
C                                      ACCUMULATE MINIMUM, MAXIMUM,
C                                      AND MEAN CONCENTRATIONS
C
      DO 320 J=1,NJ
      DO 320 KC=1,KCON
      IF(CMIN(J,KC).GT.C(J,KC)) CMIN(J,KC)=C(J,KC)
      IF(CMAX(J,KC).LT.C(J,KC)) CMAX(J,KC)=C(J,KC)
  320 SUMC(J,KC)=SUMC(J,KC)+C(J,KC)
      IF (NOPRT.EQ.0) GO TO 4500
      IF (NSTPRT.LT.ITCPRT) GO TO 4500
      IF (LOCPRT.LT.NOCTOT) GO TO 4500
      CALL QPRINT
 4500 CONTINUE
C
C
C                                      END QUALITY CYCLE LOOP
C
  548 CONTINUE
      RETURN
      END
```

* * * *

```
      SUBROUTINE DAMS(SUMQ)                                             DAMS   1
C                                                                       DAMS   2
C                                        COMPUTES ADVECTION OF          DAMS   3
C                                        CONCENTRATION DUE TO FLOW      DAMS   4
C                                        OVER DAMS                      DAMS   5
C                                                                       DAMS   6
C                                        SPECIFICATION STATEMENTS       DAMS   7
C                                                                       DAMS   8
C                                                                       DAMS   9
C                                        INTERNAL VARIABLES             DAMS  10
C                                                                       DAMS  11
      DIMENSION SUMQ(100)                                               DAMS  12
C                                                                       DAMS  13
C                                        BLANK COMMON                   DAMS  14
C                                                                       DAMS  15
      COMMON JGW,NTC,NOCYC,DELTQ,QE,QF,ALPHA(30),TITLSW(30),ICOL(10)    DAMS  16
     1 ,ISWCH(10),XR(11),XME(15,11),XMF(11),XMEO(15,11)                 DAMS  17
     2 ,N5,N6,N10,N20,N30,N40,NSTART,XRCU(15,11)                        DAMS  18
C                                                                       DAMS  19
C                                        JUNCTIONS                      DAMS  20
C                                                                       DAMS  21
      COMMON NJ, NCHAN(50,8), QIN(50), QOU(50), VOL(50), VOLO(50),
     X       AS(50)
C                                                                       DAMS  24
C                                        CHANNELS                       DAMS  25
C                                                                       DAMS  26
      COMMON NC, NJUNC(100,2), Q(100), LEN(100), U(100)
C                                                                       DAMS  28
C                                        SOURCE DATA                    DAMS  29
C                                                                       DAMS  30
      COMMON NJSW,JSW(20)                                               DAMS  31
     1,MJSW,ISW(100),CT(11,100,2),INSTM                                 DAMS  32
C                                                                       DAMS  33
C                                        QUALITY                        DAMS  34
C                                                                       DAMS  35
      COMMON KCON, C2(11), CS(15,11), ICON(11), C(50,11), SUMC(50,11),
     1       CMAX(50,11), CMIN(50,11), MADD(50,11), DCDT(50,11),
     2       CE(11,50,2), TE(11), TEP(11), SLOPE(20), CSPIN(50,11),
     3       TEC(11)
C                                                                       DAMS  39
C                                        LINKAGE AND DECAY COEFFICIENTS DAMS  44
C                                                                       DAMS  45
      COMMON /DECAY/ MAP(13), MODCHL, MODNIT, MODP, MODO2, MODBOD,
     1               MODCOL, MODMET, SUNRIS, SUNSET, AVGLIT, EXCOEF,
     2               TEMP(50), GRAZE(50), RRESP, GTCOEF, COEF(50,8),
     3               CONSTN, CONSTP, AZINCH, PINCH, OZINCH, BENTH(50),
     4               SATLIT, THETA(8), RAMM(50), RTRITE(50), RTRATE(50),
     5               RP(50), RLAER(50), DEOXY(50), RCOLIF(50),
     6               RMETAL(50), A(100), B(100), CCHAN(100), MAPBCK(13)
C                                                                       DAMS  53
C                                        DAM DATA                       DAMS  54
C                                                                       DAMS  55
      COMMON /DAM/ NDAM,JDAM(50,2),SPILL(100)                           DAMS  56
C                                                                       DAMS  57
C                                        TIDAL JUNCTION DATA            DAMS  58
```

```
* * * *
C
      COMMON /TIDAL/ NTIDE,JTIDE(15)
C
C                                     PHYSICAL DATA
C
      COMMON /PHYS/ DEP(50), ELEV(50), R(100)
C
C                                     TITLING
C
      COMMON /LBL/ COUT(12,4)
      COMMON /STI/ TITEL(40)
C
C                                     IF NO DAMS, RETURN TO LOOPQL
C
      IF(NDAM.EQ.0) RETURN
C
C                                     COMPUTE ADVECTION
C
      DO 30 KDAM=1,NDAM
      JUP=JDAM(KDAM,1)
      JDOWN=JDAM(KDAM,2)
      IF(JDOWN.GT.NJ) GO TO 30
      SUMQ(JDOWN)=SUMQ(JDOWN)+SPILL(JDOWN)
      DO 20 KC=1,KCON
      IF(MAPBCK(KC).NE.9) GO TO 10
      HOT=TEMP(JUP)
      OSAT=(14.65-(0.3898     *HOT)
     1            +(0.006969  *HOT*HOT)
     2            -(0.00005897*HOT*HOT*HOT))
     3      *((1.0-(0.00000697*ELEV(JUP)/0.3048))**5.167)
      FACTOR=1.0+0.3608*(1.0+0.046*HOT)*ABS(ELEV(JUP)-ELEV(JDOWN))
      CDAM=((FACTOR-1.0)*OSAT+C(JUP,KC))/FACTOR
      DCDT(JDOWN,KC)=DCDT(JDOWN,KC)+SPILL(JDOWN)*(CDAM-C(JDOWN,KC))
      GO TO 20
   10 CONTINUE
      DCDT(JDOWN,KC)=DCDT(JDOWN,KC)+SPILL(JDOWN)*(C(JUP,KC)-C(JDOWN,KC))
   20 CONTINUE
   30 CONTINUE
C
C                                     RETURN TO LOOPQL
C
      RETURN
      END
```

```
* * * *
      SUBROUTINE LINK(TIME,J)                                           LINK   1
C                                                                       LINK   2
C                                       COMPUTES PARAMETER DECAY AND    LINK   3
C                                       LINKAGES BETWEEN PARAMETERS     LINK   4
C                                                                       LINK   5
C                                       SPECIFICATION STATEMENTS        LINK   6
C                                                                       LINK   7
C                                                                       LINK   9
C                                       BLANK COMMON                    LINK  10
C                                                                       LINK  11
C                                                                       QP11  12
C                                       GENERAL AND CONTROL             QP11  13
C                                                                       QP11  14
      COMMON /TAPES/ INCNT,IOUTCT,JIN(10),JOUT(10),NSCRAT(5)            QP11  15
C                                                                       QP11  16
C                                       BLANK COMMON                    QP11  17
C                                                                       QP11  18
      COMMON JGW,NTC,NQCYC,DELTQ,QE,QF,ALPHA(30),TITLSW(30),ICOL(10)    QP11  19
     1 ,ISWCH(10),XR(11),XME(15,11),XMF(11),XMEO(15,11)                 QP11  20
     2 ,N5,N6,N10,N20,N30,N40,NSTART,XROU(15,11)                        QP11  21
C                                                                       QP11  22
C                                       JUNCTIONS                       QP11  23
C                                                                       QP11  24
      COMMON NJ, NCHAN(50,8), QIN(50), QOU(50), VOL(50), VOLO(50),        1
     X        AS(50)                                                      1
C                                                                       QP11  27
C                                       CHANNELS                        QP11  28
C                                                                       QP11  29
      COMMON NC, NJUNC(100,2), Q(100), LEN(100), U(100)                   1
C                                                                       QP11  31
C                                       SOURCE DATA                     QP11  32
C                                                                       QP11  33
      COMMON NJSW,JSW(20)                                               QP11  34
     1,MJSW,ISW(100),CT(11,100,2),INSTM                                 QP11  35
C                                                                       QP11  36
C                                       QUALITY                         QP11  37
C                                                                       QP11  38
      COMMON KCON, C2(11), CS(15,11), ICON(11), C(50,11), SUMC(50,11),    1
     1        CMAX(50,11), CMIN(50,11), MADD(50,11), DCDT(50,11),         1
     2        CE(11,50,2), TE(11), TEP(11), SLOPE(20), CSPIN(50,11),      1
     3        TEO(11)                                                     1
C                                                                       QP11  42
C                                       PRINTING                        QP11  43
C                                                                       QP11  44
      COMMON NQPRT,ITCPRT,LQCPRT,NSTPRT,NQCTOT,ISKIP,MSTPRT,NPRT,KPRT   QP11  45
C                                                                       QP11  46
C                                       LINKAGE AND DECAY COEFFICIENTS  QP11  47
C                                                                       QP11  48
      COMMON /DECAY/ MAP(15), MODCHL, MODNIT, MODP, MODO2, MODBOD,
     1               MODCOL, MODMET, SUNRIS, SUNSET, AVGLIT, EXCOEF,
     2               TEMP(50), GRAZE(50), RRESP, GTCOEF, RAMM(50),
     3               RTRITE(50), RTRATE(50), RP(50), REAER(50),
     4               DEOXY(50), RCOLIF(50), RMETAL(50), CONSTN,
     5               CONSTP, A2INCH, PINCH, O2INCH, BENTH(50), SATLIT,
     6               THETA(8), COEF(50,8), A(100), P(100), CCHAN(100),
* * * *
     7                    MAPHCH(13)
      COMMON /PHYS/ DEP(50), ELEV(50), R(150)
C
C                                          INITIALIZE VARIABLES
C
      K=MAP(2)
      IF(K.NE.0)       PHOS=C(J,K)
      K=MAP(3)
      IF(K.NE.0)       COLIF=C(J,K)
      K=MAP(4)
      IF(K.NE.0)       AMM=C(J,K)
      K=MAP(5)
      IF(K.NE.0)       TRITE=C(J,K)
      K=MAP(6)
      IF(K.NE.0)       TRATE=C(J,K)
      K=MAP(7)
      IF(K.NE.0)       BOD=C(J,K)
      K=MAP(8)
      IF(K.NE.0)       CHLORA=C(J,K)
      K=MAP(9)
      IF(K.NE.0)       O2=C(J,K)
      K=MAP(11)
      IF(K.NE.0)        ETAL=C(J,K)
      HOT=TEMP(J)
      DELDAY=DELTQ/86400.
C
C                                          CHLOROPHYLL A PRELIMINARY
C                                          COMPUTATIONS
C
      IF (MODCHL.EQ.0)    GO TO 30
      HOUR=(TIME-86400.*IFIX(TIME/86400.))/3600.
      DEATH=GRAZE(J)
      IF(HOUR.LT.SUNRIS) GO TO 10
      IF(HOUR.GT.SUNSET) GO TO 10
      PHOTO=SUNSET-SUNRIS
      AMBLIT=1.57*AVGLIT/PHOTO*SIN(3.14159/PHOTO*(HOUR-12.0+PHOTO/2.0))
      GO TO 20
   10 AMBLIT=0.0
      RESP=RRESP*HOT
      DEATH=DEATH+RESP
   20 EXTINC=EXCOEF*(ELEV(J)+DEP(J))
      ALPHA0=AMBLIT/SATLIT
      ALPHA1=ALPHA0/EXP(EXTINC)
      SUN=1.0/EXP(ALPHA1)-1.0/EXP(ALPHA0)
      IF (MODNIT.EQ.1)    FACTN = 1.0/((CONSTN/(AMM+TRITE+TRATE))+1.0)
      IF (MODP.EQ.1)    FACTP = PHOS/(CONSTP+PHOS)
      GROLIM=1.0
      IF ((MODNIT.EQ.1).AND.(MODP.EQ.1))    GROLIM = AMIN1(FACTN,FACTP)
      IF ((MODNIT.EQ.1).AND.(MODP.EQ.0))    GROLIM = FACTN
      IF ((MODP.EQ.1).AND.(MODNIT.EQ.0))    GROLIM = FACTP
      GROWTH=2.718*CTCOEF*HOT*SUN*GROLIM/EXTINC
C
C                                          NITROGEN COMPOUNDS
C
   30 IF (MODNIT.EQ.0)    GO TO 40
```

```
* * * *
      DELAMM=RAMM(J)*AMM*DELDAY                                         LINK  82
      AMM=AMM-DELAMM                                                    LINK  83
      IF(AMM.LE.0.0) AMM=0.0                                            LINK  84
      DELNO2=RTRITE(J)*TRITE*DELDAY                                     LINK  85
      TRITE=TRITE+DELAMM-DELNO2                                         LINK  86
      IF(TRITE.LE.0.0) TRITE=0.0                                        LINK  87
      TRATE=(1.0-RTRATE(J)*DELDAY)*TRATE+DELNO2                         LINK  88
      IF(TRATE.LE.0.0) TRATE=0.0                                        LINK  89
      IF (MODCHL.EQ.0)    GO TO 40
      UPTAKE=AZINCH*GROWTH*CHLORA*DELDAY                                LINK  91
      IF(UPTAKE.GT.(AMM+TRATE)) TRITE=TRITE-UPTAKE+AMM+TRATE            LINK  92
      IF(TRITE.LE.0.0) TRITE=0.0                                        LINK  93
      IF(UPTAKE.GT.AMM) TRATE=TRATE-UPTAKE+AMM                          LINK  94
      IF(TRATE.LE.0.0) TRATE=0.0                                        LINK  95
      AMM=AMM-UPTAKE                                                    LINK  96
      IF(AMM.LE.0.0) AMM=0.0                                            LINK  97
C                                                                       LINK  98
C                                     PHOSPHOROUS                       LINK  99
C                                                                       LINK 100
   40 IF (MODP.EQ.1)    PHOS = (1.0-RP(J)*DELDAY)*PHOS
      IF ((MODP.EQ.1).AND.(MODCHL.EQ.1))
     X     PHOS = PHOS-PINCH*GROWTH*CHLORA*DELDAY
      IF(PHOS.LE.0.0) PHOS=0.0                                          LINK 103
C                                                                       LINK 104
C                                     DISSOLVED OXYGEN                  LINK 105
C                                                                       LINK 106
      IF (MODO2.EQ.0)    GO TO 50
      OSAT=(14.65-(0.3898     *HOT)                                     LINK 108
     1             +(0.006969  *HOT*HOT)                                LINK 109
     2             -(0.00005897*HOT*HOT*HOT))                           LINK 110
     3       *((1.0-(0.00000697*ELEV(J)/0.3048))**5.167)                LINK 111
      DODT= REAER(J)*(OSAT-O2)                                          LINK 112
     1      -DEOXY(J)*BOD                                               LINK 113
     2      -BENTH(J)/(ELEV(J)*DEP(J))                                  LINK 114
      IF (MODNIT.EQ.1)    DODT = DODT-(3.43*DELAMM+1.14*DELNO2)/DELDAY
      IF (MODCHL.EQ.1)    DODT = DODT+O2INCH*(GROWTH-RESP)*CHLORA
      O2=O2+DODT*DELDAY                                                 LINK 117
      IF(O2.LE.0.0) O2=0.0                                              LINK 118
C                                                                       LINK 119
C                                     BIO-CHEMICAL OXYGEN DEMAND        LINK 120
C                                                                       LINK 121
   50 IF ((MODBOD.EQ.1).OR.(MODO2.EQ.1))
     X      BOD = (1.0-DEOXY(J)*DELDAY)*BOD
      IF(BOD.LE.0.0) BOD=0.0                                            LINK 123
C                                                                       LINK 124
C                                     COMPLETE CHLOROPHYLL A            LINK 125
C                                     COMPUTATIONS                      LINK 126
C                                                                       LINK 127
      IF (MODCHL.EQ.1)    CHLORA = (1.0+(GROWTH-DEATH)*DELDAY)*CHLORA
      IF(CHLORA.LE.0.0) CHLORA=0.0                                      LINK 129
C                                                                       LINK 130
C                                     COLIFORMS                         LINK 131
C                                                                       LINK 132
      IF (MODCOL.EQ.1)    COLIF = (1.0-RCOLIF(J)*DELDAY)*COLIF
      IF(COLIF.LE.0.0) COLIF=0.0                                        LINK 134
```

```
* * * *
C                                                                       LINK 135
C                                       METALLIC ION                    LINK 136
C                                                                       LINK 137
      IF (MODMET.EQ.1)   ETAL = (1.0-RMETAL(J)*DELDAY)*ETAL
      IF(ETAL.LE.0.0) ETAL=0.0                                          LINK 139
C                                                                       LINK 140
C                                       STORE NEW VALUES OF VARIABLES   LINK 141
C                                                                       LINK 142
      K=MAP(2)                                                          LINK 143
      IF(K.NE.0)      C(J,K)=PHOS                                       LINK 144
      K=MAP(3)                                                          LINK 145
      IF(K.NE.0)      C(J,K)=COLIF                                      LINK 146
      K=MAP(4)                                                          LINK 147
      IF(K.NE.0)      C(J,K)=AMM                                        LINK 148
      K=MAP(5)                                                          LINK 149
      IF(K.NE.0)      C(J,K)=TRITE                                      LINK 150
      K=MAP(6)                                                          LINK 151
      IF(K.NE.0)      C(J,K)=TRATE                                      LINK 152
      K=MAP(7)                                                          LINK 153
      IF(K.NE.0)      C(J,K)=BOD                                        LINK 154
      K=MAP(8)                                                          LINK 155
      IF(K.NE.0)      C(J,K)=CHLORA                                     LINK 156
      K=MAP(9)                                                          LINK 157
      IF(K.NE.0)      C(J,K)=O2                                         LINK 158
      K=MAP(11)                                                         LINK 159
      IF(K.NE.0)      C(J,K)= ETAL                                      LINK 160
C                                                                       LINK 161
C                                       RETURN TO LOOPQL                LINK 162
C                                                                       LINK 163
      RETURN                                                            LINK 164
      END                                                               LINK 165
```

```
* * * *
      SUBROUTINE SWQUAL
C
C                                        RECEIVING WATER QUALITY
C
C
C                                        SPECIFICATION STATEMENTS
C
      REAL MADD,LEN
C
C                                        GENERAL AND CONTROL
C
      COMMON /TAPES/ INCNT,IOUTCT,JIN(10),JOUT(10),NSCRAT(5)
C
C                                        BLANK COMMON
C
      COMMON JGW,NTC,NOCYC,DELTQ,QE,QF,ALPHA(30),TITLSW(30),ICOL(10)
     1 ,ISWCH(10),XR(11),XME(15,11),XMF(11),XMEO(15,11)
     2 ,N5,N6,N10,N20,N30,N40,NSTART,XROD(15,11)
C
C                                        JUNCTIONS
C
      COMMON NJ, NCHAN(50,8), QIN(50), QOU(50), VOL(50), VOLD(50),
     X        AS(50)
C
C                                        CHANNELS
C
      COMMON NC, NJUNC(100,2), Q(100), LEN(100), U(100)
C
C                                        SOURCE DATA
C
      COMMON NJSW,JSW(20)
     1,MJSW,ISW(100),CT(11,100,2),INSTM
C
C                                        QUALITY
C
      COMMON KCON, C2(11), CS(15,11), ICON(11), C(50,11), SUMC(50,11),
     1        CMAX(50,11), CMIN(50,11), MADD(50,11), DCDT(50,11),
     2        CE(11,50,2), TE(11), TEP(11), SLOPE(20), CSPIN(50,11),
     3        TEO(11)
C
C                                        PRINTING
C
      COMMON NCPRT,ITCPRT,LCCPRT,NSTPRT,NOCTOT,ISKIP,MSTPRT,NPRT,KPRT
C
C                                        LINKAGE AND DECAY COEFFICIENTS
C
      COMMON /DECAY/ MAP(13), MODCHL, MODNIT, MODP, MODO2, MODBOD,
     1               MODCOL, MODMET, SUNRIS, SUNSET, AVGLIT, EXCOEF,
     2               TEMP(50), GRAZE(50), RRESP, GTCOEF, COEF(50,8),
     3               CONSTN, CONSTP, AZINCH, PINCH, O2INCH, BENTH(50),
     4               SATLIT, THETA(6), RAMM(50), RTRITE(50), RTRATE(50),
     5               RP(50), REAER(50), DEOXY(50), RCOLIF(50),
     6               RMETAL(50), A(100), B(100), CCHAN(100), MAPBCK(13)
C
C                                        DAM DATA
```

```
* * * *
C                                                                       SWQU  56
      COMMON /DAM/ NDAM,JDAM(50,2),SPILL(100)                           SWQU  57
C                                                                       SWQU  58
C                                       TIDAL JUNCTION DATA             SWQU  59
C                                                                       SWQU  60
      COMMON /TIDAL/ NTIDE,JTIDE(15)                                    SWQU  61
C                                                                       SWQU  62
C                                       PHYSICAL DATA                   SWQU  63
C                                                                       SWQU  64
      COMMON /PHYS/ DEP(50), ELEV(50), R(100)
C                                                                       SWQU  66
C                                       TITLING                         SWQU  67
C                                                                       SWQU  68
      COMMON /LBL/ COUT(12,4)                                           SWQU  69
      N20 = NSCRAT(1)                                                   SWQU  70
      INSTM=0                                                           SWQU  71
      MODP   = 0
      MODCOL = 0
      MODNIT = 0
      MODBOD = 0
      MODCHL = 0
      MODO2  = 0
      MODMET = 0
C                                                                       SWQU  79
C                                       CALL TO SUBROUTINE INQUAL       SWQU  80
C                                                                       SWQU  81
      CALL INQUAL                                                       SWQU  82
C                                                                       SWQU  83
C                                       MAIN QUALITY LOOP               SWQU  84
C                                                                       SWQU  85
      DO 751 NTAG=NSTART,NTC                                            SWQU  86
      REWIND N1C                                                        SWQU  87
      NSTPRT = NTAG                                                     SWQU  88
C                                                                       SWQU  89
C                                                                       SWQU  90
C                                       CALL TO QUALITY CYCLE SUBROUTINESWQU  91
C                                                                       SWQU  92
      CALL LOOPQL                                                       SWQU  93
      INSTM=INSTM+1                                                     SWQU  94
C                                                                       SWQU  95
C                                       PRINT DAY AVERAGE CONCENTRATIONSSWQU  96
C                                                                       SWQU  97
      DO 359 J = 1,NJ                                                   SWQU  98
      DO 359 KC=1,KCON                                                  SWQU  99
  359 SUMC(J,KC)=(SUMC(J,KC)-0.5*C(J,KC))/(FLOAT(NQCYC))                SWQU 100
      IF (NTAG.LT.KPRT) GO TO 3220                                      SWQU 101
      IF (NTAG.GT.KPRT.AND.KPRT.EQ.1) GO TO 1600                        SWQU 102
      GO TO 4300                                                        SWQU 103
 1600 WRITE(N6,3030)                                                    SWQU 104
 3030  FORMAT(42H KPRT IS ALWAYS GOING TO BE LESS THAN NTAG)            SWQU 105
      STOP 5555                                                         SWQU 106
 4300 CONTINUE                                                          SWQU 107
      KPRT=KPRT+NPRT                                                    SWQU 108
  752 CONTINUE                                                          SWQU 109
      DO 322 KC=1,KCON                                                  SWQU 110
```

```
* * * *
      WRITE(6,101) ALPHA                                                SWQU 111
  101 FORMAT (1H1, 15A4/ 1H , 15A4////)
      WRITE(6,321) NTAG,KC,(COUT(KC,II),II=1,4),ICOL                    SWQU 116
      WRITE(N6,4100) TITLSW                                             SWQU 117
 4100 FORMAT(1H0,15A4,15A4)                                             SWQU 118
  321 FORMAT(1H0,10X,38HAVERAGE JUNCTION CONCENTRATIONS DURING,         SWQU 119
     121H TIDAL OR TIME CYCLE ,I4,21H, CONSTITUENT NUMBER ,             SWQU 120
     2I3,5X,4A4//9X,10I10/14H    JUNCTIONS.)                            SWQU 121
      DO 110 I=1,NJ,10                                                  SWQU 122
      L=MIN0(I+9,NJ)                                                    SWQU 123
  110 WRITE (6,111) I,L,(SUMC(J,KC),J=I,L)                              SWQU 124
  111 FORMAT(I4,5H  TO ,I3,1X,10E10.4)                                  SWQU 125
      IF(ISWCH(2).EQ.1) GO TO 322                                       SWQU 126
      WRITE (6,112)                                                     SWQU 127
  112 FORMAT(1H0,50X,8HMAXIMUMS/11H   JUNCTION)                         SWQU 128
      DO 113 I=1,NJ,10                                                  SWQU 129
      L=MIN0(I+9,NJ)                                                    SWQU 130
  113 WRITE (6,111) I,L,(CMAX(J,KC),J=I,L)                              SWQU 131
      WRITE (6,114)                                                     SWQU 132
  114 FORMAT(1H0,50X,8HMINIMUMS/11H   JUNCTION)                         SWQU 133
      DO 115 I=1,NJ,10                                                  SWQU 134
      L=MIN0(I+9,NJ)                                                    SWQU 135
  115 WRITE (6,111) I,L,(CMIN(J,KC),J=I,L)                              SWQU 136
  322 CONTINUE                                                          SWQU 137
C                                                                       SWQU 138
C                                       RESET SUMS FOR NEXT DAY CYCLE   SWQU 139
C                                                                       SWQU 140
 3220 CONTINUE                                                          SWQU 141
      DO 323 J=1,NJ                                                     SWQU 142
      VOLO(J)=VOL(J)                                                    SWQU 143
      DO 323 KC=1,KCON                                                  SWQU 144
      CMAX(J,KC)=0.                                                     SWQU 145
      CMIN(J,KC)=C(J,KC)                                                SWQU 146
  323 SUMC(J,KC)=0.5*C(J,KC)                                            SWQU 147
      IF (NTAG.EQ.NTC) GO TO 4140                                       SWQU 148
      REWIND N10                                                        SWQU 149
C                                                                       SWQU 150
C                                       ISWCH 10 SET BY N30 READ-IN     SWQU 151
C                                                                       SWQU 152
      IF (ISWCH(10).EQ.1) GO TO 4140                                    SWQU 153
      DO 4120 I=1,NCCYC                                                 SWQU 154
      READ (N20) NQ,(Q(N),U(N),R(N),N=1,NC),(VOL(J),QIN(J),QOU(J),      SWQU 155
     1 ELEV(J),SPILL(J),J=1,NJ)                                         SWQU 156
      WRITE(N10) NQ,(Q(N),U(N),R(N),N=1,NC),(VOL(J),QIN(J),QOU(J),      SWQU 157
     1 ELEV(J),SPILL(J),J=1,NJ)                                         SWQU 158
 4120 CONTINUE                                                          SWQU 159
      REWIND N10                                                        SWQU 160
 4140 CONTINUE                                                          SWQU 161
C                                                                       SWQU 162
C                                                                       SWQU 163
C                                       END OF MAIN DO-LOOP             SWQU 164
C                                                                       SWQU 165
  751 CONTINUE                                                          SWQU 166
      IF (ISWCH(3).EQ.1) GO TO 4160                                     SWQU 167
      RETURN                                                            SWQU 168
```

```
* * * *
C                                                                       SWQU 169
C                                        RESTART OPTION REMOVED TEMPORARY SWQU 170
C                                                                       SWQU 171
 4160 CONTINUE                                                          SWQU 172
      RETURN                                                            SWQU 173
      END                                                               SWQU 174
```

```
* * * *
      SUBROUTINE QPRINT                                                 QPRI   1
C                                                                       QPRI   2
C                                                                       QPRI   3
C                                       PRINT ROUTINE FOR QUALITY       QPRI   4
C                                       CYCLE OUTPUT.                   QPRI   5
C                                                                       QPRI   6
C                                                                       QPRI   7
C                                       SPECIFICATION STATEMENTS        QPRI   8
C                                                                       QPRI   9
      REAL MADD,LEN                                                     QPRI  10
C                                                                       QPRI  12
C                                       GENERAL AND CONTROL             QPRI  13
C                                                                       QPRI  14
      COMMON /TAPES/ INCNT,IOUTCT,JIN(10),JOUT(10),NSCRAT(5)            QPRI  15
C                                                                       QPRI  16
C                                       BLANK COMMON                    QPRI  17
C                                                                       QPRI  18
      COMMON JGW,NTC,NQCYC,DELTQ,QE,QF,ALPHA(30),TITLSW(30),ICOL(10)    QPRI  19
     1 ,ISWCH(10),XR(11),XME(15,11),XMF(11),XMEO(15,11)                 QPRI  20
     2 ,N5,N6,N10,N20,N30,N40,NSTART,XRQO(15,11)                        QPRI  21
C                                                                       QPRI  22
C                                       JUNCTIONS                       QPRI  23
C                                                                       QPRI  24
      COMMON NJ, NCHAN(50,8), QIN(50), QOU(50), VOL(50), VOLO(50),
     X       AS(50)
C                                                                       QPRI  27
C                                       CHANNELS                        QPRI  28
C                                                                       QPRI  29
      COMMON NC, NJUNC(100,2), Q(100), LEN(100), U(100)
C                                                                       QPRI  31
C                                       SOURCE DATA                     QPRI  32
C                                                                       QPRI  33
      COMMON NJSW,JSW(20)                                               QPRI  34
     1,MJSW,ISW(100),CT(11,100,2),INSTM                                 QPRI  35
C                                                                       QPRI  36
C                                       QUALITY                         QPRI  37
C                                                                       QPRI  38
      COMMON KCON, C2(11), CS(15,11), ICON(11), C(50,11), SUMC(50,11),
     1       CMAX(50,11), CMIN(50,11), MADD(50,11), DCDT(50,11),
     2       CE(11,50,2), TE(11), TEP(11), SLOPE(20), CSPIN(50,11),
     3       TEO(11)
C                                                                       QPRI  42
C                                       PRINTING                        QPRI  43
C                                                                       QPRI  44
      COMMON NQPRT,ITCPRT,LCCPRT,NSTPRT,NQCTOT,ISKIP,MSTPRT,NPRT,KPRT   QPRI  45
C                                                                       QPRI  46
C                                       LINKAGE AND DECAY COEFFICIENTS  QPRI  47
C                                                                       QPRI  48
      COMMON /DECAY/ MAP(13), MODCHL, MODNIT, MODP, MODO2, MODBOD,
     1               MODCOL, MODMET, SUNRIS, SUNSET, AVGLIT, EXCOEF,
     2               TEMP(50), GRAZE(50), RRESP, GTCOEF, COEF(50,8),
     3               CONSTN, CONSTP, AZINCH, PINCH, O2INCH, BENTH(50),
     4               SATLIT, THETA(8), RAMM(50), RTRITE(50), RTRATE(50),
     5               RP(50), REAER(50), DLOXY(50), RCOLIF(50),
     6               RMETAL(50), A(100), B(100), CCHAN(100), MAPBCK(13)
```

```
* * * *
C
C                                  DAM DATA
C
      COMMON /DAM/ NDAM,JDAM(50,2),SPILL(100)
C
C                                  TIDAL JUNCTION DATA
C
      COMMON /TIDAL/ NTIDE,JTIDE(15)
C
C                                  PHYSICAL DATA
C
      COMMON /PHYS/ DEP(50), ELEV(50), R(100)
C
C                                  TITLING
C
      COMMON /LBL/ COUT(12,4)
      IF (ISKIP.NE.NQPRT) GO TO 5020
      NQCTOT = NQCTOT + 1
 4100 FORMAT(1H015A4,15A4)
      WRITE(N6,101) ALPHA
      WRITE (N6,4100) TITLSW
  101 FORMAT (1H1, 15A4/ 1H , 15A4///)
      WRITE(N6,321) NSTPRT,MSTPRT
  321 FORMAT(43H0JUNCTION CONCENTRATIONS, DURING TIME CYCLE,I4,15H ,QUAL
     1ITY CYCLE,I4,37H. UNITS ARE MG/L, EXCEPT 10**6 MPN/L ,
     210HCOLIFORMS.//)
      WRITE(N6,325) ((COUT(K,J),J=1,2),K=1,KCON)
  325 FORMAT(9H0JUNCTION,11(2X,2A4))
      WRITE(N6,326) ((COUT(K,J),J=3,4),K=1,KCON)
  326 FORMAT(1H ,8X,11(2X,2A4)/1H )
      DO 322 J=1,NJ
      WRITE(N6,111) J,(C(J,K),K=1,KCON)
  111 FORMAT(1H ,I6,2X,11F10.3)
  322 CONTINUE
      ISKIP = 1
      GO TO 5010
 5020 CONTINUE
      ISKIP = ISKIP + 1
 5010 CONTINUE
      RETURN
      END
```

```
* * * *
      SUBROUTINE INQUAL
C
C                                      QUALITY DATA INPUT ROUTINE
C
C
C                                      SPECIFICATION STATEMENTS
C
      REAL MADD,LEN
      DIMENSION VAR(13),CONST(4)
C
C                                      GENERAL AND CONTROL
C
      COMMON /TAPES/ INCNT,IOUTCT,JIN(10),JOUT(10),NSCRAT(5)
C
C                                      BLANK COMMON
C
      COMMON JGW,NTC,NQCYC,DELTQ,QE,QF,ALPHA(30),TITLSW(30),ICOL(10)
     1 ,ISWCH(10),XR(11),XME(15,11),XMF(11),XMEO(15,11)
     2 ,N5,N6,N10,N20,N30,N40,NSTART,XROD(15,11)
C
C                                      JUNCTIONS
C
      COMMON NJ, NCHAN(50,8), QIN(50), QOU(50), VOL(50), VOLJ(50),
     X       AS(50)
C
C                                      CHANNELS
C
      COMMON NC, NJUNC(100,2), Q(100), LEN(100), U(100)
C
C                                      SOURCE DATA
C
      COMMON NJSW,JSW(20)
     1,MJSW,ISW(100),CT(11,100,2),INSTM
C
C                                      QUALITY
C
      COMMON KCON, C2(11), CS(15,11), ICON(11), C(50,11), SUMC(50,11),
     1       CMAX(50,11), CMIN(50,11), MADD(50,11), DCDT(50,11),
     2       CE(11,50,2), TE(11), TEP(11), SLOPE(20), CSPIN(50,11),
     3       TCO(11)
C
C                                      PRINTING
C
      COMMON NQPRT,ITCPRT,LCCPRT,NSTPRT,NQCTOT,ISKIP,MSTPRT,NPRT,KPRT
C
C                                      LINKAGE AND DECAY COEFFICIENTS
C
      COMMON /DECAY/ MAP(13), MODCHL, MODNIT, MODP, MOD02, MODBOD,
     1               MODCOL, MODMET, SUNRIS, SUNSET, AVGLIT, EXCOEF,
     2               TEMP(50), GRAZE(50), RESP, GTCOEF, COEF(50,8),
     3               CONSTN, CONSTP, AZINCH, PINCH, O2INCH, BENTH(50),
     4               SATLIT, THETA(8), RAMM(50), RTRITE(50), RTRATE(50),
     5               RP(50), REAER(50), DEOXY(50), RCOLIF(50),
     6               RMETAL(50), A(100), B(100), CCHAN(100), MAPBCK(13)
C
```

```
* * * *
C                                            DAM DATA
C
      COMMON /DAM/ NDAM,JDAM(50,2),SPILL(100)
C
C                                            TIDAL JUNCTION DATA
C
      COMMON /TIDAL/ NTIDE,JTIDE(15)
C
C                                            PHYSICAL DATA
C
      COMMON /PHYS/ DEP(50), ELEV(50), R(100)
C
C                                            TITLING
C
      COMMON /LBL/ COUT(12,4)
      COMMON/CARD/TITLE(4,13)
C
C                                            DATA DECLARATIONS
C
      DATA                  NAME/4HREAE/
C
C                                            SET-UP I/O DATA SETS
C
      N5=5
      N6=6
C
C                                            READ N10,N30,N40. N10 SHOULD BE
C                                            DRUM OR DISC STORAGE. N30 AND
C                                            N40 SHOULD BE MAGNETIC TAPE,
C                                            IF USED.
C
      N10 = NSCRAT(2)
      N30 = NSCRAT(3)
      N40 = NSCRAT(4)
      REWIND N10
      REWIND N20
C
C
      READ(N5,555) ISWCH
  555 FORMAT (10I5)
      IF(ISWCH(1).EQ.1) REWIND N30
      IF(ISWCH(3).EQ.1) REWIND N40
      DO 11 I=1,10
      ICOL(I)=I
   11 CONTINUE
      WRITE(N6,6) ICOL,ISWCH
    6 FORMAT(15H1SWITCH SETTINGS/(10I10))
C
C                                            INITIALIZATION
C
      DO 5100 J=1,50
      TEMP(J)=0.0
      GRAZE(J)=0.0
      BENTH(J)=0.0
      RAMM(J)=0.0
```

* * * *

```
      RTRITE(J)=0.0                                                     INQU 111
      RTRATE(J)=0.0                                                     INQU 112
      RP(J)=0.0                                                         INQU 113
      DEOXY(J)=0.0                                                      INQU 114
      REAER(J)=0.0                                                      INQU 115
      RCOLIF(J)=0.0                                                     INQU 116
      RMETAL(J)=0.0                                                     INQU 117
      DO 5050 I=1,8                                                     INQU 118
      COEF(J,I)=0.0                                                     INQU 119
 5050 CONTINUE                                                          INQU 120
      DO 5100 K=1,11                                                    INQU 121
      C(J,K)=0.0                                                        INQU 122
      MADD(J,K)=0.0                                                     INQU 123
 5100 CONTINUE                                                          INQU 124
      DO 5110 I=1,8                                                     INQU 125
      THETA(I)=0.0                                                      INQU 126
 5110 CONTINUE                                                          INQU 127
      DO 5120 I=1,15                                                    INQU 128
      DO 5120 K=1,11                                                    INQU 129
      CS(I,K)=0.0                                                       INQU 130
 5120 CONTINUE                                                          INQU 131
      DO 5130 N=1,100
      A(N)=0.0                                                          INQU 133
      B(N)=0.0                                                          INQU 134
      CCHAN(N)=0.0                                                      INQU 135
 5130 CONTINUE                                                          INQU 136
      DO 5150 I=1,6                                                     INQU 137
      TE(I) =0.0                                                        INQU 138
      TEP(I)=0.0                                                        INQU 139
      DO 5140 L=1,20                                                    INQU 140
      CE(I,L,1)=0.0                                                     INQU 141
      CE(I,L,2)=0.0                                                     INQU 142
 5140 CONTINUE                                                          INQU 143
 5150 CONTINUE                                                          INQU 144
C                                                                       INQU 145
C                                       NETWORK   DATA ARE READ FROM    INQU 146
C                                       RECEIVING WATER QUANTITY PROGRAMINQU 147
C                                                                       INQU 148
      READ (N20) TITLSH,ALPHA,NJ,NC,NOCYC,DELTQ,((NCHAN(J,K),K=1,6),    INQU 149
     1 AS(J),DEP(J),J=1,NJ),(LEN(N),(NJUNC(N,K),K=1,2),N=1,NC),         INQU 150
     2 NTIDE,(JTIDE(M),M=1,NTIDE),NDAM,((JDAM(M,N),N=1,2),M=1,NDAM)     INQU 151
C                                                                       INQU 152
C                                       FLOW DATA ARE TRANSFERRED       INQU 153
C                                       TO FAST STORAGE. DRUM OR DISC.  INQU 154
C                                                                       INQU 155
      DO 90 I=1,NOCYC                                                   INQU 156
      READ (N20) NQ,(Q(N),U(N),R(N),N=1,NC),(VOL(J),QIN(J),QOU(J),      INQU 157
     1 ELEV(J),SPILL(J),J=1,NJ)                                         INQU 158
      WRITE(N10) NQ,(Q(N),U(N),R(N),N=1,NC),(VOL(J),QIN(J),QOU(J),      INQU 159
     1 ELEV(J),SPILL(J),J=1,NJ)                                         INQU 160
   90 CONTINUE                                                          INQU 161
      REWIND N10                                                        INQU 162
      IF(ISWCH(1).NE.1) GO TO 95                                        INQU 163
C                                                                       INQU 164
C                                       RESTART OPTION TEMPORARILY      INQU 165
```

```
* * * *
C                                                 ELIMINATED AT THIS POINT          INQU 166
C                                                                                   INQU 167
   95 READ (N5,555) NJSW,ITCPRT,NQPRT,LQCPRT,NTC,NPRT                               INQU 168
      WRITE (N6,101) ALPHA                                                          INQU 169
  101 FORMAT (1H1, 15A4/ 1H , 15A4/ 1H //)
      WRITE (N6,4100) TITLSW                                                        INQU 174
 4100 FORMAT (1H0,15A4,15A4)                                                        INQU 175
      WRITE (N6,1100) NJ                                                            INQU 176
 1100 FORMAT (24H0MAXIMUM JUNCTION NUMBER,I5)                                       INQU 177
      WRITE (N6,1102) NC                                                            INQU 178
 1102 FORMAT (23H0MAXIMUM CHANNEL NUMBER,I5)                                        INQU 179
      WRITE (N6,1104) NQCYC                                                         INQU 180
 1104 FORMAT (33H0NUMBER OF QUALITY CYCLES PER DAY,I5)                              INQU 181
      WRITE (N6,1105) NTC                                                           INQU 182
 1105 FORMAT (15H0NUMBER OF DAYS,I5)                                                INQU 183
      WRITE (N6,1106) DELTQ                                                         INQU 184
 1106 FORMAT (45H0LENGTH OF QUALITY INTEGRATION STEP (SECONDS),F7.0)                INQU 185
      WRITE (N6,1110) NPRT                                                          INQU 186
 1110 FORMAT (16H0PRINT INTERVAL,,I4,5H DAYS)                                       INQU 187
      WRITE (N6,4200) NJSW                                                          INQU 188
 4200 FORMAT (10H0THERE ARE,I3,25H SOURCE INPUTS FROM CARDS)                        INQU 189
      MTOTAL=LQCPRT*NQPRT                                                           INQU 190
      WRITE (N6,5040) ITCPRT,NQPRT,MTOTAL                                           INQU 191
 5040 FORMAT ('0QUALITY CYCLE CONCENTRATIONS PRINTOUT STARTS IN TIME',
     1        ' CYCLE', I3, ' PRINTED EVERY', I3, ' CYCLE(S), FOR A',
     2        ' TOTAL OF ', I3, ' CYCLES')
C                                                                                   INQU 195
C                                                 READ QUALITY INITIALIZATION       INQU 196
C                                                 AND BOUNDARY DATA                 INQU 197
      DO 8010 KCX=1,13                                                              INQU 198
      MAP(KCX)=0                                                                    INQU 199
 8010 CONTINUE                                                                      INQU 200
      DO 8020 KCNC=1,8                                                              INQU 201
      THETA(KCNC)=0.0                                                               INQU 202
 8020 CONTINUE                                                                      INQU 203
      JCHECK=NJ                                                                     INQU 204
      INTEG=0                                                                       INQU 205
      NITCHK=0                                                                      INQU 206
      KCON=0                                                                        INQU 207
      GO TO 8031                                                                    INQU 208
 8030 ISWCH(4)=1                                                                    INQU 209
 8031 READ (N5,9010) (CONST(I),I=1,4),INTEG,(VAR(I),I=1,12)                         INQU 210
 9010 FORMAT (4A4,I4,12F5.0)                                                        INQU 211
      IF(INTEG.NE.0) GO TO 8080                                                     INQU 212
      IF(JCHECK.NE.NJ) STOP  11                                                     INQU 213
      JCHECK=0                                                                      INQU 214
      DO 8040 KCC=1,13                                                              INQU 215
      IVAR=KCC                                                                      INQU 216
      IF(CONST(1).EQ.TITLE(1,KCC)) GO TO 8050                                       INQU 217
 8040 CONTINUE                                                                      INQU 218
      STOP 12                                                                       INQU 219
 8050 IF(IVAR.NE.5) GO TO 8051                                                      INQU 220
      IF(CONST(2).EQ.TITLE(2,6)) IVAR=6                                             INQU 221
 8051 IF(IVAR.EQ.12) GO TO 8031                                                     INQU 222
      KCON=KCON+1                                                                   INQU 223
```

```
* * * *
      MAP(IVAR)=KCON
      MAPBCK(KCON)=IVAR
      GO TO (8031,8061,8062,8063,8064,8065,8067,8068,8069,8030,8070,
     1       8031,8140),IVAR
 8061 IF (MODP.EQ.1)   STOP 21
      MODP = 1
      THETA(4) = VAR(1)
      GO TO 8030
 8062 IF (MODCOL.EQ.1)   STOP 22
      MODCOL = 1
      THETA(7) = VAR(1)
      GO TO 8030
 8063 THETA(1) = VAR(1)
      GO TO 8066
 8064 THETA(2) = VAR(1)
      GO TO 8066
 8065 THETA(3) = VAR(1)
 8066 MODNIT = 1
      NITCHK=NITCHK+IVAR
      GO TO 8030
 8067 IF (MODBOD.EQ.1)   STOP 23
      MODBOD = 1
      THETA(6)=VAR(1)
      GO TO 8030
 8068 IF (MODCHL.EQ.1)   STOP 24
      MODCHL = 1
      SUNRIS = VAR(1)
      SUNSET = VAR(2)
      AVGLIT = VAR(3)
      SATLIT = VAR(4)
      EXCOEF = VAR(5)
      GTCOEF = VAR(6)
      RRESP  = VAR(7)
      CONSTN = VAR(8)
      CONSTP = VAR(9)
      AZINCH = VAR(10)
      PINCH  = VAR(11)
      O2INCH = VAR(12)
      GO TO 8030
 8069 IF (MODO2.EQ.1)   STOP 25
      MODO2 = 1
      THETA(5) = VAR(1)
      GO TO 8030
 8070 IF (MODMET.EQ.1)   STOP 26
      MODMET = 1
      THETA(8)=VAR(1)
      GO TO 8030
 8080 JCHECK=MAX0(JCHECK,INTEG)
      JTT=INTEG
      IF(IVAR.EQ.12) GO TO 8100
      C(JTT,KCON)=VAR(1)
      MADE(JTT,KCON)=VAR(2)
      GO TO (8110,8091,8092,8093,8094,8095,8096,8097,8098,8110,8099),
     1 IVAR
 8091 RF(JTT)=VAR(3)
```

```
* * * *
      GO TO 8110                                                        INQU 279
 8092 NCOLIF(JTT)=VAR(3)                                                INQU 280
      GO TO 8110                                                        INQU 281
 8093 HAMM(JTT)=VAR(3)                                                  INQU 282
      GO TO 8110                                                        INQU 283
 8094 RTRITE(JTT)=VAR(3)                                                INQU 284
      GO TO 8110                                                        INQU 285
 8095 RTNATE(JTT)=VAR(3)                                                INQU 286
      GO TO 8110                                                        INQU 287
 8096 DEOXY(JTT)=VAR(3)                                                 INQU 288
      GO TO 8110                                                        INQU 289
 8097 GRAZE(JTT)=VAR(3)                                                 INQU 290
      GO TO 8110                                                        INQU 291
 8098 BENTH(JTT)=VAR(3)                                                 INQU 292
      GO TO 8110                                                        INQU 293
 8099 RMETAL(JTT)=VAR(3)                                                INQU 294
      GO TO 8110                                                        INQU 295
 8100 TEMP(JTT)=VAR(1)                                                  INQU 296
      GO TO 8031                                                        INQU 297
 8110 IF(NTIDE.EQ.0) GO TO 8030                                         INQU 298
      DO 8120 KTIDE=1,NTIDE                                             INQU 299
      IF(JTT.EQ.JTIDE(KTIDE)) GO TO 8130                                INQU 300
 8120 CONTINUE                                                          INQU 301
      GO TO 8030                                                        INQU 302
 8130 CS(KTIDE,KCON)=VAR(4)                                             INQU 303
      XRQD(KTIDE,KCON)=VAR(5)                                           INQU 304
      GO TO 8030                                                        INQU 305
 8140 IF ((MODNIT.EQ.1).AND.(NITCHK.NE.15))   STOP 31
      IF ((MODO2.EQ.1).AND.(MODBOD.EQ.0))   STOP 32
      KCON=KCON-1                                                       INQU 308
C                                                                       INQU 309
C                                          LIST INITIALIZATION          INQU 310
C                                          AND BOUNDARY DATA            INQU 311
C                                                                       INQU 312
      WRITE (N6,9020)                                                   INQU 313
 9020 FORMAT (32H0CONSTITUENTS BEING MODELED ARE-)                      INQU 314
      IOUT=0                                                            INQU 315
      DO 8160 IVAR=1,11                                                 INQU 316
      IF(MAP(IVAR).EQ.0) GO TO 8160                                     INQU 317
      IOUT=IOUT+1                                                       INQU 318
      MAPOUT=MAP(IVAR)                                                  INQU 319
      DO 8150 I=1,4                                                     INQU 320
      COUT (MAPOUT,I)=TITLE(I,IVAR)                                     INQU 321
 8150 CONTINUE                                                          INQU 322
 8160 CONTINUE                                                          INQU 323
      IOUT=IOUT+1                                                       INQU 324
      DO 8161 I=1,4                                                     INQU 325
      COUT(IOUT,I)=TITLE(I,12)                                          INQU 326
 8161 CONTINUE                                                          INQU 327
      WRITE (N6,9030) ((COUT(I,J),J=1,4),I=1,KCON)                      INQU 328
 9030 FORMAT (1H0,6(4A4,4X)/1H ,6(4A4,4X))                              INQU 329
      WRITE (N6,9040)                                                   INQU 330
 9040 FORMAT (43H1INITIAL CONCENTRATIONS (MG/L), BY JUNCTION)           INQU 331
      WRITE (N6,9050) ((COUT(K,J),J=1,2),K=1,IOUT)                      INQU 332
 9050 FORMAT (9H0JUNCTION,12(2X,2A4))                                   INQU 333
```

* * * *

```
      WRITE (N6,9060) ((COUT(K,J),J=3,4),K=1,IOUT)
 9060 FORMAT (1H ,8X,12(2X,2A4)/1H )
      DO 7010 J=1,NJ
      WRITE (N6,9070) J,(C(J,K),K=1,KCON),TEMP(J)
 7010 CONTINUE
 9070 FORMAT (1H ,I6,2X,12F10.3)
      WRITE (N6,9080)
 9080 FORMAT (44H1BACKGROUND MASS LOADING (MG/L), BY JUNCTION)
      WRITE (N6,9050) ((COUT(K,J),J=1,2),K=1,KCON)
      WRITE (N6,9060) ((COUT(K,J),J=3,4),K=1,KCON)
      DO 7020 J=1,NJ
      WRITE (N6,9070) J,(MADD(J,K),K=1,KCON)
 7020 CONTINUE
      IF(NTIDE.EQ.0) GO TO 7050
      WRITE (N6,9160)
 9160 FORMAT (50H1CONCENTRATIONS (MG/L) OF OCEAN SINKS, BY JUNCTION)
      WRITE (N6,9050) ((COUT(K,J),J=1,2),K=1,KCON)
      WRITE (N6,9060) ((COUT(K,J),J=3,4),K=1,KCON)
      DO 7030 M=1,NTIDE
      J=JTIDE(M)
      WRITE (N6,9070) J,(CS(M,K),K=1,KCON)
 7030 CONTINUE
      WRITE (N6,9170)
 9170 FORMAT (45H1EXCHANGE RATIOS FOR OCEAN SINKS, BY JUNCTION)
      WRITE (N6,9050) ((COUT(K,J),J=1,2),K=1,KCON)
      WRITE (N6,9060) ((COUT(K,J),J=3,4),K=1,KCON)
      DO 7040 M=1,NTIDE
      J=JTIDE(M)
      WRITE (N6,9070) J,(XROD(M,K),K=1,KCON)
 7040 CONTINUE
 7050 WRITE (N6,9120)
 9120 FORMAT(62H1REACTION RATES FOR NON-CONSERVATIVE CONSTITUENTS, BY JU
     1NCTION)
      WRITE (N6,9130)
 9130 FORMAT ( 9H0JUNCTION,11X,89HPHOSPHOR  COLIFORM  AMMONIA   NITRITES
     1 NITRATES  DEOXYGEN  GRAZING   BENTHIC   METAL ION,/1H )
      DO 7060 J=1,NJ
      WRITE (N6,9140) J,RP(J),RCOLIF(J),RAMM(J),RTRITE(J),RTRATE(J),
     1 DEOXY(J),GRAZE(J),BENTH(J),RMETAL(J)
 7060 CONTINUE
 9140 FORMAT (I6,13X,9(F8.3,2X))
      IF (MODCHL.EQ.0)   GO TO 8165
      WRITE (N6,9150) SUNRIS,SUNSET,AVGLIT,SATLIT,EXCOEF,GTCOEF,RRESP,
     1                CONSTN,CONSTP
 9150 FORMAT(34H0PARAMETERS FOR CHLOROPHYLL A ARE-/1H ,5X,
     A35HSUNRISE                                   =,F5.2,
     B24H HOURS                   ,
     C40HSUNSET                                         =,F5.2,
     D16H HOURS          /1H ,
     E35HAVERAGE DAILY SOLAR RADIATION      =,F5.2,
     F24H LANGLEYS/DAY            ,
     G40HSOLAR RADIATION SATURATION                 =,F5.2,
     H16H LANGLEYS/DAY      /1H ,
     I35HEXTINCTION COEFFICIENT             =,F5.2,
     J24H 1/METERS                /1H
```

* * * *

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     K35HTEMPERATURE COEFFICIENT OF GROWTH =,F5.2,
     L24H                    ,
     M40HTEMPERATURE COEFFICIENT OF RESPIRATION =,F5.2/1H ,
     N35HMICHAELIS CONSTANT FOR NITROGEN    =,F5.2,
     O24H MICROGRAM N/LITER     ,
     P40HMICHAELIS CONSTANT FOR PHOSPHORUS       =,F5.2,
     Q18H MICROGRAM P/LITER)
      WRITE(N6,9151) AZINCH,PINCH,O2INCH
 9151 FORMAT(1H ,
     A35HNITROGEN RATIO                     =,F5.2,
     B24H MG N/MG CHL A          ,
     C40HPHOSPHOROUS RATIO                       =,F5.2,
     D18H MG P/MG CHL A     /1H ,
     E35HOXYGEN RATIO                       =,F5.2,
     F24H MG O2/MG CHL A          )
 8165 WRITE (N6,9180)
 9180 FORMAT (55H0TEMPERATURE ADJUSTMENT COEFFICIENTS FOR REACTION RATES
     1)
      WRITE (N6,9190) (THETA(I),I=1,8)
 9190 FORMAT (16H0AMMONIA       =,F10.3,4X,15HNITRITES       =,F10.3,4X
     1 15HNITRATES       =,F10.3,4X,15HPHOSPHORUS     =,F10.3/16H REAERATI
     2ON     =,F10.3,4X,15HDEOXYGENATION =,F10.3,4X,15HCOLIFORMS      =,
     3 F10.3,4X,15HMETAL ION      =,F10.3)
C
C                                           READ REAERATION COMPUTATION
C                                           COEFFICIENTS AND LIST, IF O2
C                                           BEING MODELED
C
      IF (MODO2.EQ.0)    GO TO 8180
      DO 8170 N=1,NC
      READ (N5,9200) ID,ICHAN,A(ICHAN),B(ICHAN),CCHAN(ICHAN)
      IF(ID.NE.NAME) STOP 41
 8170 CONTINUE
      WRITE (N6,9210)
 9200 FORMAT(A4,6X,I5,3F10.0)
 9210 FORMAT (67H1CHANNEL CHARACTERISTICS FOR COMPUTATION OF REAERATION
     1COEFFICIENTS/36H0CHANNEL       A          B          C/1H )
      WRITE (N6,9220) (N,A(N),B(N),CCHAN(N),N=1,NC)
 9220 FORMAT (1H ,I5,F12.3,2F10.3)
C
C                                            ADDITIONAL POINT SOURCE
C                                            INPUTS FROM CARDS.
C
      IF(NJSW.EQ.0) GO TO 8180
      READ(N5,9230) (JSW(L),L=1,NJSW)
 9230 FORMAT(16I5)
      DO 8171 K=1,KCON
C
C                                         READ TIME AND LOADING RATES
C
      READ(N5,9240) (CONST(I),I=1,4),TE(K),(CE(K,L,2),L=1,NJSW)
 9240 FORMAT(4A4,F10.0,9F6.0,/,11F6.0)
      TEP(K)=TE(K)/3600.
      WRITE(N6,9250) (CONST(I),I=1,4),TEP(K)
 9250 FORMAT(1H0,10X,23H ADDITIONAL SOURCES OF ,4A4,4H AT ,F5.2,
* * * *
     1 17H HOURS FROM START,/,1H0,10X,                                   INQU 444
     2 120HJUNCTION MASS RATE  JUNCTION MASS RATE  JUNCTION MASS RATE J  INQU 445
     3UNCTION MASS RATE  JUNCTION MASS RATE  JUNCTION MASS RATE  ,1H0)   INQU 446
      WRITE(N6,9260) (JSW(L),CE(K,L,2),L=1,NJSW)                         INQU 447
 9260 FORMAT(1H ,6(I5,F11.2))                                            INQU 448
 8171 CONTINUE                                                           INQU 449
C                                                                        INQU 450
C                                     SET-UP DATA FOR SWQUAL             INQU 451
C                                                                        INQU 452
 6180 NSTART =1                                                          INQU 453
      KPRT = 1                                                           INQU 454
      NQCTOT = 1                                                         INQU 455
      ISKIP = 1                                                          INQU 456
      DO 230 J=1,NJ                                                      INQU 457
      VOLD(J)=VOL(J)                                                     INQU 458
      DO 230 KC = 1,KCON                                                 INQU 459
      CSPIN(J,KC)=MADD(J,KC)                                             INQU 460
      SUMC(J,KC)=0.5*C(J,KC)                                             INQU 461
      CMAX(J,KC)=0.                                                      INQU 462
      CMIN(J,KC)=C(J,KC)                                                 INQU 463
  230 CONTINUE                                                           INQU 464
   39 CONTINUE                                                           INQU 465
      RETURN                                                             INQU 466
      END                                                                INQU 467
```

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* * * *
      SUBROUTINE ADJUST                                                 ADJU   1
C                                                                       ADJU   2
C                                        SPECIFICATION STATEMENTS       ADJU   3
C                                                                       ADJU   4
C                                                                       QP11  12
C                                        GENERAL AND CONTROL            QP11  13
C                                                                       QP11  14
      COMMON /TAPES/ INCNT,IOUTCT,JIN(10),JOUT(10),NSCRAT(5)            QP11  15
C                                                                       QP11  16
C                                        BLANK COMMON                   QP11  17
C                                                                       QP11  18
      COMMON JGW,NTC,NUCYC,DELTQ,QL,QF,ALPHA(30),TITLSW(30),ICOL(10)    QP11  19
     1 ,ISWCH(10),XR(11),XME(15,11),XMF(11),XMEO(15,11)                 QP11  20
     2 ,N5,N6,N10,N20,N30,N40,NSTART,XROD(15,11)                        QP11  21
C                                                                       QP11  22
C                                        JUNCTIONS                      QP11  23
C                                                                       QP11  24
      COMMON NJ, NCHAN(50,8), JIN(50), QOU(50), VOL(50), VOLJ(50),         1
     X       AS(50)                                                        1
C                                                                       QP11  27
C                                        CHANNELS                       QP11  28
C                                                                       QP11  29
      COMMON NC, NJUNC(100,2), Q(100), LEN(100), U(100)                    1
C                                                                       QP11  31
C                                        SOURCE DATA                    QP11  32
C                                                                       QP11  33
      COMMON NJSW,JSW(20)                                               QP11  34
     1,MJSW,ISW(100),CT(11,100,2),INSTM                                 QP11  35
C                                                                       QP11  36
C                                        QUALITY                        QP11  37
C                                                                       QP11  38
      COMMON NCON, C2(11), CS(15,11), ICON(11), DUMMY(50,11),
     X       SUPC(50,11),
     1       CMAX(50,11), CMIN(50,11), MADD(50,11), DCDT(50,11),           1
     2       CE(11,50,2), TE(11), TLP(11), SLOPE(20), CSPIN(50,11),        1
     3       TEO(11)                                                       1
C                                                                       QP11  42
C                                        PRINTING                       QP11  43
C                                                                       QP11  44
      COMMON NOPRT,ITCPRT,LOCPRT,NSTPRT,NUCTOT,ISKIP,MSTPRT,NPRT,KPRT   QP11  45
C                                                                       QP11  46
C                                        LINKAGE AND DECAY COEFFICIENTS QP11  47
C                                                                       QP11  48
      COMMON /DECAY/ MAF(13), MODCHL, MCONIT, MODP, MODO2, MODBOD,         1
     1               MOLCOL, MODMET, SUNRIS, SUNSET, AVELIT, EXCOEF,       1
     2               TEMP(50), GRAZE(50), RRESP, GTCOEF, COEF(50,8),
     3               CONSTN, CONSTP, AZINCH, PINCH, O2INCH, BENTH(50),
     4               SATLIT, THETA(8), COEF2(50,8),
     5               A(100), B(100), C(100), MAPBCK(13)
C
      COMMON /PHYS/ DEP(50), ELEV(50), R(100)                              1
      DIMENSION DEOXY(50), REAER(50), DENOM(50)
C                                                                       ADJU  18
      EQUIVALENCE (DEOXY(1),COEF(1,6)),(REAER(1),COEF(1,5))             ADJU  19
C                                                                       ADJU  20
```

```
* * * *
C                                          PHYSICAL DATA
C
C
C                                          COMPUTE CHANNEL REAERATION
C                                          COEFFICIENTS AND PREPARE FOR
C                                          WEIGHTED AVERAGES AT NODES
C
      DO 10 J=1,50
      DENOM(J)=0.0
      REAER(J)=0.0
   10 CONTINUE
      DO 20 N=1,NC
      IF(R(N) .LE. 0.0) GOTO 20
      CHANKR= A(N)*((3.2808*ABS(U(N)))**B(N))/((3.2808*R(N))**C(N))
      J1=NJUNC(N,1)
      J2=NJUNC(N,2)
      ADDEND=ABS(Q(N))
      DENOM(J1)=DENOM(J1)+ADDEND
      DENOM(J2)=DENOM(J2)+ADDEND
      ADDEND=ADDEND*CHANKR
      REAER(J1)=REAER(J1)+ADDEND
      REAER(J2)=REAER(J2)+ADDEND
   20 CONTINUE
C
C                                          COMPUTE ADJUSTED REACTION
C                                          RATES FOR EACH JUNCTION
C
      DO 60 J=1,NJ
      IF(NCHAN(J,1).EQ.0) GO TO 60
      IF(DENOM(J) .EQ. 0.0) GOTO 60
      REAER(J)=REAER(J)/DENOM(J)
      DEOXY(J)=COEF20(J,6)
      DEPTH=ELEV(J)+DEP(J)
      IF(DEPTH .LE. 0.0) GOTO 60
      IF(DEPTH.LT.2.44) DEOXY(J)=DEOXY(J)/((DEPTH/2.44)**0.434)
      DO 50 K=1,8
      GO TO (30,30,30,30,40,40,30,30),K
   30 IF(THETA(K).EQ.0.0) GO TO 50
      COEF(J,K)=COEF20(J,K)*(THETA(K)**(TEMP(J)-20.0))
      GO TO 50
   40 IF(THETA(K).EQ.0.0) GO TO 50
      COEF(J,K)=COEF(J,K)*(THETA(K)**(TEMP(J)-20.0))
   50 CONTINUE
   60 CONTINUE
      RETURN
      END
```

```
* * * *
      SUBROUTINE RECUAL
      COMMON /TAPES/ INCNT,IOUTCT,JIN(10),JOUT(10),NSCRAT(5)           RECE   2
      DIMENSION QUAN(2),QUAL(2),ANAME(4)                               RECE   3
      DATA QUAN(1),QUAN(2)/4HQUAN,4HTITY/                              RECE   4
      DATA QUAL(1),QUAL(2)/4HQUAL,4HITY /                              RECE   5
      N5=5                                                             RECE   6
      N6=6                                                             RECE   7
      INCNT=INCNT+1                                                    RECE   8
      READ (N5,100) (ANAME(I),I=1,4)                                   RECE   9
  100 FORMAT(4A4,I4)                                                   RECE  10
  150 IF(ANAME(3).EQ.QUAL(1).AND.ANAME(4).EQ.QUAL(2)) CALL SWQUAL      RECE  12
  400 WRITE(N6,500)                                                    RECE  17
  500 FORMAT (31H0RECEIVING SIMULATION COMPLETED)                      RECE  18
      RETURN                                                           RECE  19
      END                                                              RECE  20
```

```
* * * *
      BLOCK DATA TITLE2
      COMMON /CARD/ TITLE(4,13)
      DATA TITLE /4HSULF,4HATES,4H    ,4H    ,
     A            4HTOTA,4HL FE,4H    ,4H    ,
     B            4HMANG,4HANES,4HE   ,4H    ,
     C                        4HAMMO,4HNIA ,4H    ,4H    ,
     D                        4HNITR,4HITE ,4H    ,4H    ,
     E                        4HNITR,4HATE ,4H    ,4H    ,
     F            4HALUM,4HINUM,4H    ,4H    ,
     G                        4HCHLO,4HROPH,4HYLL ,4HA   ,
     H                        4HDISS,4HOLVE,4HD OX,4HYGEN,
     I            4HTDS ,4H    ,4H    ,4H    ,
     J            4HTSS ,4H    ,4H    ,4H    ,
     K                         4HTEMP,4HERAT,4HURE ,4H    ,
     L                         4HLAST,4H CON,4HSTIT,4HUENT/
      END
```

APPENDIX C

SSWMM - RECEIV II INPUT REQUIREMENTS

SSWMM INPUT

FORMAT	COLUMNS	VARIABLE	DESCRIPTION	CARD
I2	1-2	JOUT	OUTPUT FILE FOR LNKPRQ (0 IF NOT CREATING AN OUTPUT FILE)	1
20A4	1-80	TITLE	1 DESCRIPTIVE TITLE CARD	2
I2	1-2	IDBAS	BASIN IDENTIFICATION	3
I2	3-4	NSTEP	# OF TIME STEPS	
I2	5-6	NHR	HOUR OF START OF STORM	
I2	7-8	NMM	MINUTES OF START OF STORM	
F5.0	9-13	DELT	TIME STEP LENGTH (SEC)	
F5.0	14-18	PCTZER	% OF IMPERVIOUS AREA WITH ZERO DETENTION (ARTIFICIAL-25%)	
I2	19-20	NSAVE	# OF ELEMENTS WHOSE FLOWS AND POLLUTANT MASS LOADS ARE TO BE PRINTED (MAX=50) INLETS AND ANY SUBCATCHMENTS	
I2	21-22	INLETS	# OF INLETS (MAX=20) BOTTOM OF RUNOFF AREA OR SYSTEM (EACH INLET MUST BE THE LAST DOWNSTREAM ELEMENT)	
I2	23-24	NPFI	# OF POLLUTANTS TO BE SAVED ON FILE (MAX=8)	
40I2	1-2	ISAVE (1)	ELEMENT NUMBERS WHOSE FLOWS AND POLLUTANT MASS ARE TO BE PRINTED	4A
	3-4	ISAVE (2)		
	5-6	ISAVE (3)		
	79-80	ISAVE (40)		
40I2	1-2	ISAVE (41)	CARD 4B USED ONLY IF NSAVE > 40	4B
	3-4	ISAVE (42)		
	5-6	ISAVE (43)		
	.	.		
	.	.		
	.	.		
	19-20	ISAVE (50)		
40I2	1-2	ISFI (1)	INLET NUMBERS IN BASIN	5
	3-4	ISFI (2)		
	5-6	ISFI (3)		
	.	.		
	.	.		
	.	.		

SSWMM INPUT

FORMAT	COLUMNS	VARIABLE	DESCRIPTION	CARD
I5	1-5	NHISTO	# OF RAINFALL DATA POINTS (MAX=100)	6
I5	6-10	NELT	TOTAL # OF ELEMENTS (MAX=99)	
I5	11-15	NHYT	# OF HYETOGRAPHS (MAX=4)	
REPEAT CARD GROUP 7 FOR EACH HYETOGRAPH (MUST BE READ IN ORDER)				
10F5.0	1-5	RAIN(1,1)	RAINFALL INTENSITY FOR HYETOGRAPH #1 (IN/HR). DURATION OF RAINFALL INTENSITY MUST EQUAL THE TIME STEP LENGTH (DELT). NUMBER OF CARDS FOR EACH HYETOGRAPH= (NHISTO+9)/10 (TRUNCATE DECIMAL PLACES)	7
	6-10	RAIN(1,2)		
	11-15	RAIN(1,3)		
	.	.		
	.	.		
	.	.		
	45-50	RAIN(1,10)		
THE FOLLOWING INFORMATION MUST BE READ ACCORDING TO INCREASING ELEMENT ORDER REPEAT CARDS 8 AND 9 IF NCHAR (KT)=1 OR CARDS 8 AND 10 IF NCHAR (KT)=2				
I5	1-5	IELT	ELEMENT NUMBER	8
I5	6-10	NCHAR (KT)	ELEMENT TYPE (1 - WATERSHED) (2 - PIPE OR MANHOLE)	
I5	11-15	NUP(KT)	# OF UPSTREAM ELEMENTS (MAX=3)	
I5	16-20	IUP(KT,1)	1ST UPSTREAM ELEMENT	
I5	21-25	IUP(KT,2)	2ND UPSTREAM ELEMENT	
I5	26-30	IUP(KT,3)	3RD UPSTREAM ELEMENT	
I5	31-35	NRG(KT)	HYETOGRAPH NUMBER, BASED ON ORDER READ IN (VALUE NEEDED ONLY FOR WATERSHED. DEFAULT VALUE IS 1)	

SSWMM INPUT

FORMAT	COLUMNS	VARIABLE	DESCRIPTION	CARD
15X	1-15	BLANK		9
F5.0	16-20	EWIDTH(KT)	WIDTH OF OVERLAND FLOW (FT)	
F5.0	21-25	AREA(KT)	AREA OF WATERSHED (AC)	
F5.0	26-30	PCIMP(KT)	% IMPERVIOUSNESS	
F5.0	31-35	SLOPE(KT)	WATERSHED SLOPE (FT/FT)	
20X	1-20	BLANK		10
F8.0	21-28	EWIDTH(KT)	DIAMETER OF PIPE (FT)	
F8.0	29-36	GLEN(KT)	LENGTH OF PIPE (FT)	
F8.0	37-44	SLOPE(KT)	INVERT SLOPE (FT/FT) OR	
80X	1-80	BLANK	BLANK CARD IF ELEMENT IS A MANHOLE	
F8.0	1-8	G6	MANNING'S COEFFICIENT NEEDED FOR GUTTER DEPTH CALCULATIONS OR PIPE FLOWS	11
F8.0	9-16	W5	IMPERVIOUS AREA RESISTANCE FACTOR (MANNING'S COEFFICIENT)	
F8.0	17-24	W6	PERVIOUS AREA RESISTANCE FACTOR (MANNING'S COEFFICIENT)	
F8.0	25-32	WSTORE(1)	RETENTION STORAGE FOR IMPERVIOUS AREA (IN)	
F8.0	33-40	WSTORE(2)	RETENTION STORAGE FOR PERVIOUS AREA (IN)	
F8.0	41-48	WLMAX	MAXIMUM INFILTRATION RATE (IN/HR)	
F8.0	49-56	WLMIN	MINIMUM INFILTRATION RATE (IN/HR)	
F8.0	57-64	DECAY	DECAY RATE OF INFILTRATION (1/SEC)	
F8.0	65-72	FPSX	EXPONENTIAL DECAY COEFFICIENT OF POLLUTANTS OF WATERSHED	

SSWMM INPUT

FORMAT	COLUMNS	VARIABLE	DESCRIPTION	CARD
5X	1-5	BLANK		12
I5	6-10	MQUAL	CONTROL CARD TO ALLOW FOR QUALITY MODELING 0 - NO QUALITY MODELED 1 - QUALITY MODELED	
IF MQUAL = 0, SKIP CARDS 13-25				
F10.0	1-10	CBVOL	AVERAGE CATCHBASIN (VOLUME (FT^3))	13
15	11-15	NQS	NUMBER OF POLLUTANTS (MAX=8)	
15	16-20	ISS	METHOD FOR CALCULATING SUSPENDED SOLIDS (0 IF CALCULATION IS TO BE DONE THE SAME WAY AS FOR OTHER POLLUTANTS)	
F10.0	21-30	DRYDAY	NUMBER OF DRY DAYS PREVIOUS TO STORM. i.e., RAINFALL PREVIOUS TO STORM < 1.0 IN.	
8F10.0	1-10	CBFACT(1)	CONCENTRATION OF 8 POLLUTANTS IN CATCHBASINS. (THESE CONCENTRATIONS CAN BE ARBITRARILY CHOSEN AS CAN THE POLLUTANTS EXCEPT FOR SUS. SOL.)	14
	11-20	CBFACT(2)		
	21-30	CBFACT(3)		
	.	.		
	.	.		
	71-80	CBFACT(8)		
e.g.	CBFACT(1) = CONCENTRATION OF BOD, OR COD, OR . . . CBFACT(2) = CONCENTRATION OF SUS. SOL.			
8F10.0	1-10	DXFACT(1)	DUST AND DIRT LOADING RATES FOR ANY 8 ARBITRARILY CHOSEN LAND USES (LBS/DRY DAY-FT^2)	15
	11-20	DXFACT(2)		
	21-30	DXFACT(3)		
	31-40	DXFACT(4)		
	41-50	DXFACT(5)		
	51-60	DXFACT(6)		
	61-70	DXFACT(7)		
	71-80	DXFACT(8)		

SSWMM INPUT

FORMAT	COLUMNS	VARIABLE	DESCRIPTION	CARD
F10.0	1-10	XFACT(1,1)	CONCENTRATION OF 8 POSSIBLE CONSTITUENTS IN A GRAM OF DUST AND DIRT FOR FIRST LAND USE (mg/g)	16
F10.0	11-20	XFACT(1,2)		
F10.3	21-30	XFACT(1,3)	(MUST USE 8 CARDS LEAVING SOME BLANK IF NECESSARY)	
5F10.0	31-40	XFACT(1,4)		
	.	.		
	.	.		
	71-80	XFACT(1,8)		
REPEAT CARD 16 FOR LAND USES #2, #3, #4, #5, #6, #7, AND #8				17-23
8F10.0	1-10	F1(1)	FACTOR FOR INSOLUBLE POLLUTANT WITHIN SETTLEABLE SOLIDS TO BE ADDED TO POLLUTANT ALREADY WASHED FROM SURFACE	24
	11-20	F1(2)		
	21-30	F1(3)	DEFAULT ESTIMATES FROM SWMM ARE AS FOLLOWS: BOD = .02 N = .01 PO_4 = .001 OTHERS = 0.	
	.	.		
	.	.		
	.	.		
	71-80	F1(8)		
8F10.0	1-10	F2(1)	FACTOR FOR INSOLUBLE POLLUTANT WITHIN SUSPENDED SOLIDS TO BE ADDED TO POLLUTANT ALREADY WASHED FROM SURFACE	25
	11-20	F2(2)		
	21-30	F2(3)	DEFAULT ESTIMATES FROM SWMM ARE AS FOLLOWS: BOD = .05 N = .045 PO_4 = .0045 OTHERS = 0.	
	.	.		
	.	.		
	.	.		
	71-80	F2(8)		
REPEAT CARDS 26, 27, 28 FOR EACH WATERSHED (MUST BE READ IN ORDER OF COMPUTATION)				
15X	1-15	BLANK		26
F10.0	16-25	BASINS(KT)	NUMBER OF CATCHBASINS WITHIN WATERSHED	

SSWMM INPUT

FORMAT	COLUMNS	VARIABLE	DESCRIPTION	CARD
F10.0	26-35	REFF	REMOVAL EFFICIENCY (SEE TABLE BELOW)	26 (Cont)

# OF STREET SWEEPER PASSES	CLEANING FREQUENCY	REFF
2	-	.98
2	0-8	.95
2	8-15	.92
2	15	.88
1	0-8	.75
1	8-15	.70
1	15	.60

FORMAT	COLUMNS	VARIABLE	DESCRIPTION	CARD
F10.0	36-45	CLFREQ	STREET CLEANING FREQUENCY	
8F10.5	1-10	XLAND(1)	FRACTION (EXPRESSED AS A DECIMAL) OF LAND USE WITHIN WATERSHED	27
	11-20	XLAND(2)		
	21-30	XLAND(3)		
	31-40	XLAND(4)		
	41-50	XLAND(5)		
	71-80	XLAND(8)		
8F10.5	1-10	GQLEN(1)	AREA OF EACH LAND USE IN FT^2	28
	11-20	GQLEN(2)		
	21-30	GQLEN(3)		
	31-40	GQLEN(4)		
	41-50	GQLEN(5)		
	71-80	GQLEN(8)		
I2	1-2	IDWF	CONTROL CARD TO MODEL DRY WEATHER FLOW 0 - NO DRY WEATHER FLOW MODELED	29

IF IDWF = 0, SKIP THE REMAINING CARDS

SSWMM INPUT

FORMAT	COLUMNS	VARIABLE	DESCRIPTION	CARD
F10.5	1-10	DWF	BASE DRY WEATHER FLOW	30
F10.5	11-20	CBOD	BOD CONCENTRATION FACTOR	
F10.5	21-30	CSS	SUSPENDED SOLIDS CONCENTRATION FACTOR	
F10.5	31-40	CCOLI	F. COLIFORMS CONCENTRATION FACTOR	
8F10.5	1-10	DDWF(1,1)	FLOW DIURNAL VARIATION, BASED ON A 24 HOUR CYCLE	31-33
	11-20	DDWF(1,2)		
	.	.		
	.	.		
	.	.		
	71-80	DDWF(1,24)		
	REPEAT CARD GROUPS 31-33 FOR VARIATION IN			
			BOD	34-36
			SUSPENDED SOLIDS	37-39
			F. COLIFORMS	40-42

LNKPRG INTERPRETER INPUT

FORMAT	COLUMNS	VARIABLE	DESCRIPTION	CARD
I5	1-5	IFL	SSWMM OUTPUT FILE	1
I5	6-10	IF0	LNKPRG OUTPUT FILE	
F5.0	1-5	RZERO	RECEIV START UP TIME (HRS)	
F5.0	6-10	RDELT	RECEIV QUANTITY TIME-STEP LENGTH (SEC) MUST BE A MULTIPLE OF SSWMM TIME STEP	2
15	11-15	ISDY	CONTROL VARIABLE TO NOTE SSWMM START-UP TIME BEGINS ON THE NEXT DAY AFTER RECEIV START-UP TIME. (0 IF SSWMM STARTS ON SAME DAY)	
1015	1-5	NPOLL(1)	# OF POLLUTANTS TO BE PASSED AS INPUT TO RECEIV FOR EACH INLET	3
	6-10	NPOLL(2)		
	.	.		
	.	.		
	.	NPOLL(INLETS)		
			REPEAT CARDS 4 & 5 FOR EACH SOURCE INLET	
1015	1-5	NPIN(I,K)	POSITION OF POLLUTANTS IN THE SSWMM OUTPUT FILE THAT ARE TO BE PASSED TO RECEIV	4
	6-10	K=1,NPOLL(I)		
	11-15	I=1,INLETS		
	.			
	.			
	.			
1015	1-5	NPOT(I,K)	POSITION OF POLLUTANTS IN THE RECEIV INPUT ARRAY	5
	6-10			
	11-15			
	.			
	.			
	.			

LNKPRG INTERPRETER INPUT

FORMAT	COLUMNS	VARIABLE	DESCRIPTION	CARD
2A3	1-6	PTLE(1)	POLLUTANT COLUMN HEADINGS FOR LNKPRG PRINTOUT	6
2A3	7-12	PTLE(2)		
	.			
	.			
2A3	.			
2A3	61-66	PTLE(11)		
I5	1-5	NOPS	NUMBER OF ADDITIONAL POINT SOURCES	7
F5.0	6-10	TFIN	FINAL RECEIV II TIME AT END OF MODELING PERIOD - HRS	
			REPEAT CARDS 8 AND 9 FOR EACH ADDITIONAL POINT SOURCES	
I5	1-5	NAPS	ID NUMBER OF ADDITIONAL POINT SOURCES	8
F5.2	6-10	FLO	ADDITIONAL POINT SOURCE FLOW (CU M/SEC) (WITHDRAWAL IS NEGATIVE; DISCHARGE IS POSITIVE)	
F8.0	11-18	APSP(1)	ADDITIONAL POINT SOURCE MASS LOADINGS (mg/SEC) IN RECEIV INPUT ARRAY SEQUENCE	
10F80	1-8	APSP(2)	ADDITIONAL POINT SOURCE MASS LOADINGS (mg/SEC) IN RECEIVE INPUT ARRAY SEQUENCE	9
	9-16	APSP(3)		
	.	.		
	.	.		
	.	.		
	.	.		
	72-80	APSP(11)		

SETUP DATA DECK

Card Group	Number of Cards	Card Column	Description	Variable Name	Format	Default Value	Units
A	1	1-2	Check for calling of SUBROUTINE SETUP = 1, do not call SETUP = 0, CALL SETUP If RUN = 1 on Card Group A, skip remaining groups	RUN	2 ±	0	
B	2	1-80	River basin title cards	TITLE	20A4	none	
C	1	1-5	Number of nodes with source inputs (Total=storm+Additional)	MJSW	I5	none	
		6-15	Time of first source inputs with respect to model start time	TZERO	F10.0	none	hours
		16-20	Number of times at which one or more sources change input values (# RAINFALL STEPS +2)	NSTEPS	I5	none	
D	One card for each node which has one or more sources associated with it	1-5	Node number	ISW	I5	none	
		6-55	Number of each source associated with node (maximum of 10)	NS	IOI5	0	

QUANTITY DATA DECK

Card Group	Number of Cards	Card Column	Description	Variable Name	Format	Default Value	Units
1	1	1-8	If hydraulic calculations are to carried out, enter "QUANTITY." If not, leave blank and omit remaining cards.	ANAME (1) ANAME (2)	2A4	blank	
2	2	1-60	Title for run	ALPHA	15A4	blank	
3	2	1-60	Title for Basin	TITLE	15A4	blank	
4	1	1-5	Number of tidally forced junctions	NTIDE	I5	0	
		6-10	Number of dams	NDAM	I5	0	
		11-15	= 0, print input channel and junction data = 1, skip printing	ISWCH (2)	I5	0	
5	1	1-5	Number of day cycles desired	NTCYC	I5	none	
		6-10	Number of hours/day cycle (≥ 1 and ≤ 30)	PERIOD	F5.0	none	hours
		11-15	Length of quality timestep } (QINT/DELT) ≤ 12	QINT	F5.0	none	hours
		16-20	Length of hydraulic timestep	DELT	F5.0	none	seconds
		21-25	Initial time for start of hydrograph input from cards	TZERO	F5.0	none	hour
		26-30	Number of nodes for time-history printout (≤ 10)	NHPRT	I5	none	
		31-35	Number of channels for time-history printout (≤ 10)	NQPRT	I5	none	
		41-45	Evaporation	EVAP	F5.0	0	mm/hr
		46-50	Wind velocity	WIND	F5.0	0	m/sec
		51-55	Wind direction	WDIR	F5.0	none	degrees from North
		56-60	Day cycle at which printed output will start (≥ 1)	NQSWRT	I5	none	
		61-65	Number of nodes of storm water input from cards	NJSW	I5	none	
		66-70	Number of points of rain information ($\geq 2, \leq 100$)	INRAIN	I5	none	

QUANTITY DATA DECK

Card Group	Number of Cards	Card Column	Description	Variable Name	Format	Default Value	Units
6			If INRAIN = 0, SKIP CARD GROUP 6 (maximum number of points = 100, four per card)				
	maximum=25	1-10	Rate of precipitation	RAIN(1)	F10.0	none	mm/hr
		11-20	Time from model start time	INTIME(1)	F10.0	none	min
		21-30	Etc., up to INRAIN points	⋮	F10.0	none	
		31-40	⋮		F10.0	none	
7			Node(s) selected for stage-history printout; NHPRT values 8 per card				
	maximum=7	1-10	First node number	JPRT(1)	I10	none	
		11-20	Second node number	JPRT(2)	I10	none	
		⋮	⋮	⋮	⋮	⋮	
			Last node number	JPRT (NHPRT)	I10	none	
			Channels selected for flow print, NQPRT values, 8 per card				
8	maximum=7	1-7	Lower node number at end of first desired channel	CPRT(1)	I10	none	
		8-10	Higher node number at end of desired channel				
		11-17	Lower node number at end of second desired channel	CPRT(2)	I10	none	
		18-20	Higher node number at end of second desired channel				
			⋮	⋮	⋮	⋮	
			Lower node number at end of last desired channel	CPRT (NQPRT)	I10		
			Higher node number at end of last desired channel				
9	Not implemented see text						

QUANTITY DATA DECK

Card Group	Number of Cards	Card Column	Description	Variable Name	Format	Default Value	Units
10 (Type A)	One card for tidally forced junction, each Group 10A card is followed by the Group 10B cards for the same tidally forced junction		If NTIDE=0 on Card Group 4, skip Card Group 10				
		1-5	Node number of tidally-forced node	JTIDE	I5		
		6-10	If=1, will expand from tide points (HHW,LHW,LLW, HLW) for tidal coefficients	KO	I5		
		11-15	Number of tidal stage data points for junction	NI	I5		
		16-20	Maximum number of iterations for curve fit, usually 50	MAXIT	I5		
		21-25	=0, skip tidal input print =1 print all tidal parameters	NCHTID	I5		
10 (Type B)	At least two cards for each tidally-forced node; these cards follow the correspond-ing tidally-forced note, if KO=0. If KO=1 and NI=4,1 card.		IF NTIDE=0 on Card Group 10B NI pairs of values, 4 pairs/card, minimum of 7 pairs				
		1-10	Time of tidal stage, first point	TT(1)	F10.0	none	hours
		11-20	Tidal stage, first point	YY(1)	F10.0	none	meters
		21-30	Time of tidal stage, second point	TT(2)	F10.0	none	hours
		31-40	Tidal stage, second point	YY(2)	F10.0	none	meters
		⋮	⋮	⋮	⋮	⋮	⋮
			Time of tidal stage, last point	TT(NI)	F10.0	none	hours
			Tidal stage, last point	YY(NI)	F10.0	none	meters
11	One card for each dam, i.e., number of cards in Group 11 = NDAM		IF NDAM=0 on Card Group 4, skip Card Group 11				
		1-5	Node number of node immediately upstream of dam	JDAM(,1)	I5	none	
		6-10	Node number of node immediately downstream of dam	JDAM(,2)	I5	none	

QUANTITY DATA DECK

Card Group	Number of Cards	Card Column	Description	Variable Name	Format	Default Value	Units
11 (cont.)		11-20	Weir Factor=XW, where: W = width of spillway for broad or narrow crested weir = 1 for V-notched weir X = 1.8299 for narrow crested X = 1.67 for broad crested X = 1.416 tan ϕ, where ϕ = angle of notch	DAM(,1)	F10.0	none	meters
		21-30	Elevation of rest of weir, referenced to datum plane	DAM(,2)	F10.0	none	meters
		31-40	Exponent for Weir equation = 1.5 for broad and narrow crested = 2.5 for V-notched	DAM(,3)	F10.0	none	
12	One for each node (maximum = 10)	1-5	Node number	J	I5	none	
		6-10	Water surface elevation referenced to datum plane	H(J)	F5.0	none	meters
		11-20	Surface area of node*	AS(J)	F10.0	none	sq. meters
		21-25	Node constant flow into receiving waters	QIN(J)	F5.0	none	m^3/sec
		26-30	Node constant flow out of receiving waters	QOU(J)	F5.0	none	m^3/sec
		31-40	Depth of node bottom**	DEP(J)	F10.0	none	meters
		41-50	Nodal Manning's coefficient (Include Manning's coefficient if program develops geometric data)				
		51-70	(blank)				
		71-75	X - coordinate	X(J)	F5.0	none	kilometers
		76-80	Y - coordinate	Y(J)	F5.0	none	kilometers

* Half of the surface area of the previous channel plus half of the surface area of succeeding channel

** Directed positive downward from datum plane

QUANTITY DATA DECK

Card Group	Number of Cards	Card Column	Description	Variable Name	Format	Default Value	Units
13	1	1-5	To terminate node cards, write 99999		I5	none	
14	One for each channel (maximum = 10)	1-5	User assigned channel number	N	I5		
		6-10	Node at upper end of channel	NTEMP(1)	I5		
		11-15	Node at lower end of channel	NTEMP(2)	I5		
		16-20	Blank, unless TRIAN is used to develop geometric data. Node which, with first two junctions, form an acute triangle. Program will develop channels and node characteristics				
		21-25	Blank unless it is a number of a fourth node which lies between a pair of previous three junctions. Program will develop geometric data.	NTEMP(4)	I5		
		26-35	Length of channel	ALEN	F10.0		meters
		36-45	Width of Channel	WIDTH	F10.0	none	meters
		46-55	Average depth of channel (channel**)	RAD	F10.0	none	meters
		56-65	Manning's coefficient, n	COEF	F10.0	.018	
		66-75	Initial velocity	VEL	F10.0	none	m/sec
15	1	1-5	To terminate channel cards, write 99999		I5		
16 17 18	Not implemented see text						

** Directed positive downward from datum plane.

QUANTITY DATA DECK

Card Group	Number of Cards	Card Column	Description	Variable Name	Format	Default Value	Units
19	1 or 2		If NJSW = 0 on Card Group 5, skip to Card Group 22				
			Nodes for storm water input, NJSW values (maximum=20)				
		1-5	First nodes number for storm water input	JSW(1)	I5	none	
		6-10	Second nodes number for storm water input	JSW(2)	I5	none	
			Last nodes number for storm water input	JSW(NJSW)	I5	none	
20	Repeat for each time-step	1-10	Time for hydrograph	TE(1)	F10.0	none	seconds
		11-20	Flow for first node	QE(1,1)	F10.0	none	m^3/sec
		21-30	Flow for second node	QE(1,2)	F10.0	none	m^3/sec
			Flow for last node	QE (1,NJSW)	F10.0	none	m^3/sec
21	1	1-10	Terminate input hydrograph cards with TE(1) beyond expected time of analysis		F10.0	none	sec
22	1	1-8	Enter "ENDQUANT" in field (End of QUANTITY Data Deck)		2A4	none	

QUALITY DATA DECK

Card Group	Number of Cards	Card Column	Description	Variable Name	Format	Default Value	Units
1		9-15	Enter "QUALITY".	ANAME (3) ANAME (4)	2A4	blank	
2	1	6-10	Skip printing of maximum and minimum concentrations (=1)	ISWCH (2)	I5	0	
		21-25	Tidally influenced receiving water (=1)	ISWCH (5)	I5	1	
		46-50	Use only first daily cycle on input file (=1)	ISWCH(10)	I5	0	
3	1	1-5	Number of junctions with sources specified on card (max = 50)	NJSW	I5	0	
		6-10	Daily cycle at which detailed quality information will begin printing.	ITCPRT	I5	none	
		11-15	Number of cycles between printing of quality results	NQPRT	I5	none	hours
		16-20	Total number of daily cycles printed (maximum 50 cycles)	LQCPRT	I5	none	-
		21-25	Number of Daily Cycles Desired	NTC	I5	none	-
		26-30	Print interval-days NPRT = 1 to Print Every Day	NPRT	I5	none	days
4 Type A	1 Card per constituent being modeled	1-16	Name of Constituent: SULFATES TOTAL FE MANGANESE ALUMINUM TDS TSS TEMPERATURE or terminator LAST CONSTITUENT	CONST	4A4	none	-
		17-20	(Blank)				

QUALITY DATA DECK

Card Group	Number of Cards	Card Column	Description	Variable Name	Format	Default Value	Units
4 **Type A** (cont.)		21-25	Temperature Compensation coefficient (Theta) except for chlorophyll a: Time of sunrise (SUNRIS)	VAR(1)	F5.0	0	1/°C
			Following data entries for Chlorophyll a only				
		26-30	Time of sunset (SUNSET)	VAR(2)	F5.0	0	hours
		31-35	Average daily maximum light intensity (AVGLIT)	VAR(3)	F5.0	0	$\frac{\text{joule}}{\text{m}^2\text{-day}}$
		36-40	Saturation light intensity (SATLIT)	VAR(4)	F5.0	0	$\frac{\text{joule}}{\text{m}^2\text{-day}}$
		41-45	Extinction coefficient (EXCOEF)	VAR(5)	F5.0	0	1/m
		46-50	Growth coefficient (GTCOEF)	VAR(6)	F5.0	0	
		51-55	Rate of respiration (RRESP)	VAR(7)	F5.0	0	
		56-60	Michaelis constant for nitrogen	VAR(8)	F5.0	0	mg/1
		61-65	Michaelis constant for phosphorous	VAR(9)			mg/1
		66-70	Nitrogen ratio (AZINCH)	VAR(10)	F5.0	0	$\frac{\text{mg}}{\text{mg}}$
		71-75	Phosphorous ratio (PINCH)	VAR(11)	F5.0	0	$\frac{\text{mg}}{\text{mg}}$
		76-80	Oxygen ratio (O2INCH)	VAR(12)	F5.0	0	$\frac{\text{mg}}{\text{mg}}$
4 Type B	1 Card per node per constituent set	1-16	Name of constituent	CONST	4A4	none	-
		17-20	Node number		I4	0	-
		21-25	Initial concentration	VAR(1)	F5.0	0	mg/1 $\frac{10^6\text{MPN}}{1}$ °C

QUALITY DATA DECK

Card Group	Number of Cards	Card Column	Description	Variable Name	Format	Default Value	Units
4 Type B (cont.)		26-30	Background source concentration	VAR(2)	F5.0	0	mg/1 $10^6 \frac{MPN}{1}$ °C
		31-35	Reaction rate or Benthic demand (DO) or Grazing rate (chlorophyll a).	VAR(3)	F5.0	0	1/day
		36-40	Concentration of ocean sink (tidally forced node only)	VAR(4)	F5.0	0	$\frac{\text{joule}}{m^2\text{-day}}$
		41-45	Ocean exchange coefficient (XRQD)	VAR(5)	F5.0	0	
5	1 Card for each Channel when modeling oxygen	1-4	REAE-	ID	A4	none	-
		5-10	RATION	-	6X	-	-
		11-15	Channel Number	ICHAN	I5	0	-
		16-25	K_A coef. for reaeration computation	A	F10.0	0	
		26-35	K_B coef. for reaeration computation	B	F10.0	0	
		36-45	K_C coef. for reaeration computation	C	F10.0	0	
6	1 or 2, depending on number of nodes	1-5	Node number for 1st additional source node	JSW(1)	I5	0	
		6-10	Node number for 2nd additional source node	JSW(2)	I5	0	
		. . .	. . .	. . .	. . . .	. . . .	
		-	Node number for NJSW additional source node	JSW (NJSW)	I5	0	

QUALITY DATA DECK

Card Group	Number of Cards	Card Column	Description	Variable Name	Format	Default Value	Units
7	1 set per time specified; set consists of 1-2 card(s) per constituent modeled	1-16	Constituent name	CONST( )	4A4	Blank	.
		17-26	Time	TE( )	F10.0	0	s
		27-31	Mass rate for 1st node	CD( )	F6.0	0	gm/s
		32-37	Mass rate for 2nd node	CE( )	F6.0	0	gm/s
		.	.	.	.	.	.
		.	.	.	.	.	.
		.	.	.	.	.	.
		-	Mass rate for NJSW node	CE( )	F6.0	0	gm/s

APPENDIX D

SSWMM - RECEIV II INPUT LISTINGS

FOR MODEL RUNS 1,2,3, AND 4

MODEL RUN 1 - INITIAL RUN - STORM SEPT. 17, 1976

WARREN GENERATING STATION, WARREN, PA.

```
* * * *
// JOB SSWMM
// DVC RES
// LBL $LOKOITRCLIB
// LFD TRCLIB
// DVC 20
// LFD PRNTR
// DVC 20    // LFD FORT03
// DVC 51    // VOL TRCU01
// LBL 'WARREN STORM 2 SSWMM INITIAL'    // LFD FORT21
// EXEC SWIM,TRCLIB
/$
21
DATA SET STORM 2, SEPTEMBER 17, 1976  WARREN GENERATING STATION
 1400745 900.  25. 3 3 7
 3 5 6
 3 5 6
   40     6     1
  0.0   .04   .04   .04   .04   .04   .04   .05   .05   .05
  .05   .05   .05   .11   .11   .07   .07   .07   .07   .03
  .03   .03   .03   .03   .03   .03   .03   .03   .03   .03
  .03   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0
    1     1     0                         1
                     338. 2.61 100. .018
    2     2     1     1
                              1.0  153.13      .137
    3     2     1     2

    4     1     0                         1
                   488.0  1.71 100. .137
    5     2     1     4

    6     1     0                         1
                   275.0  2.53 100. .045
    7     2     1     6
                              25.      325.      .022
    8     2     1     7

   .015    0.013            0.062                0.0      0.0      0.0      4.6
          1
      0.0      7     0        21.74
      0.0           0.0       0.0        0.0        0.0        0.0
    0.003        0.003      0.003
                 593.5        1.0       18.7         .3        3.4        6.5
                 593.5        1.0       18.7         .3        3.4        6.5
                 593.5        1.0       18.7         .3        3.4        6.5




      0.0           0.0       0.0        0.0        0.0        .0
      0.            0.0       0.0        0.0        0.0        .0
                        0.0         0.0       100.0
          1.
    11[illegible].
```

```
                        0.0          0.0         100.0
                 1.
              74585.
                        0.0          0.0         100.0
                                1.
                          110355.
C
/*
/L
// FIN
```

```
* * * *
// FIN
// JOB LNKPRG
// DVC RES    // LBL $LOK011TRCLIB    // LFD TRCLIB
// DVC 20    // LFD PRNTR
// DVC 20    // LFD FORT03
// DVC 51    // VOL TRC001
// LBL 'WARREN STORM 2 SSWMM INITIAL'    // LFD FORT21
// DVC 51    // VOL TRC001
// LBL 'WARREN STORM 2 LNKPRG INITIAL'    // LFD FORT22
// EXEC LNKPRG,TRCLIB
/*
  21   22
 0.0  30.    1
   6    6    6
   2    3    4    5    6    7
  11    1    2    3    7   10
   2    3    4    5    6    7
  11    1    2    3    7   10
   2    3    4    5    6    7
  11    1    2    3    7   10
 SO4  TOT FE  MN                     AL                      TDS   TSS
   5   72
   468.661110232.
 13045.   2060.                    68660.                  7222982. 797126.
   5 -3.6  58211.
   664.    108.                     3600.                   378712.  41795.
   6  3.6  58211.
   664.    108.                     3600.                   378712.  41795.
   7-17.9 289443.
  3400.    537.                    17900.                  1883041. 207815.
   8 17.9 289443.
  3400.    537.                    17900.                  1883041. 207815.
/*
/&
// FIN
```

```
* * * *
// JOB QUAN
// DVC RES    // LBL BLOKDITRCLIB    // LFD TRCLIB
// DVC 20    // LFD PRNTR
// DVC 20    // LFD FORT05
// DVC 51    // VOL TRC001
// LBL 'WARREN STORM 2 LNKPRG INITIAL'    // LFD FORT21
// DVC 51    // VOL TRC001
// LBL 'WARREN STORM 2 SETUP'    // LFD FORT23
// DVC 51    // VOL TRC001
// LBL SLSCRAT2    // LFD FORT24
// DVC 51    // VOL TRC001
// LBL 'WARREN STORM 2 QUAN'    // LFD FORT25
// DVC 51    // VOL TRC001
// LBL SLSCRAT4    // LFD FORT26
// DVC 51    // VOL TRC001
// LBL SLSCRAT7    // LFD FORT27
// DVC 51    // VOL TRC001
// LBL SLSCRAT5    // LFD FORT28
// EXEC QUAN,TRCLIB
/*
 (
DATA SET STORM 2, SEPTEMBER 17, 1976  WARREN GENERATING STATION
STORM CONTAINS 43 RAINFALL STEPS
     4         0.0   42
     1    4
     4    1     2     5
     5    3     6     7
     9    6
QUANTITYQUALITY
DATA SET STORM 2, SEPTEMBER 17,1976  WARREN GENERATING STATION
ALL LOADINGS TREATED AS FINITE SOURCES
BASIN CONTAINS 3 SUBCATCHMENTS,2 PIPES,AND 3 INLETS
TOTAL AREA = 6.85 ACRES
     0    1     0
     3  24.    .1  30.  0.0    10     8        0.0  0.0  0.0     1     0     0
          1          2          3          4          5          6          7          8
          9         10
       1  2       2  3       3  4       4  5       5  6       6  7       7  8       8  9
     9   10     265.01       0.0        1.5
     1 5.13   134072.                 -1.89      .033
     2 2.69   111646.                 -1.59      .033
     3 2.69    29350.                 -1.54      .033
     4 2.69    23184.                 -1.17      .033
     5 2.69    39378.                 -1.17      .033
     6 2.69    64644.                 -1.17      .033
     7 2.69    75948.                 -1.17      .033
     8 2.69    80203.                  -.80      .033
     9 1.47    47265.                            .033
    10 0.25    47265.                  +.79      .033
99999
     1    1     2              1334.       135.      -1.74       .033        .33
     2    2     3               370.       106.      -1.56       .033        .33
     3    3     4               161.       121.      -1.36       .033        .33
     4    4     5               161.       167.      -1.17       .033        .33
     5    5     5               307.       167.      -1.17       .033        .33
    6     6     7                     460.       167.      -1.17      .033       .33
    7     7     8                     383.       172.       -.98      .033       .33
    8     8     9                     693.       137.       -.40      .033       .33
99999
ENDQUANT
/*
/&
// FIN
```

```
* * * *
// JOB UTLNPS
// DVC RES   // LBL $LOKJ1TRCLIB   // LFD TRCLIB
// DVC 20   // LFD PRNTR
// DVC 20   // LFD FORT03
// DVC 51   // VOL TRC001
// LBL 'WARREN STORM 2 SETUP'   // LFD FORT23
// DVC 51   // VOL TRC001
// LBL 'WARREN STORM 2 QUAN'   // LFD FORT25
// DVC 51   // VOL TRC001
// LBL SLSCRAT4   // LFD FORT26
// DVC 51   // VOL TRC001
// LBL SLSCRAT7   // LFD FORT27
// DVC 51   // VOL TRC001
// LBL SLSCRAT8   // LFD FORT28
// EXEC UTLNPS,TRCLIB
/&
        QUALITY
         U              0                        0
    0    1   20   36    3    1
SULFATES              1.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
SULFATES           112.00
SULFATES           212.00
SULFATES           312.00
SULFATES           412.00
SULFATES           512.00
SULFATES           612.00
SULFATES           712.00
SULFATES           812.00
SULFATES           912.00
SULFATES          1012.00
TOTAL FE              1.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
TOTAL FE           1 0.15
TOTAL FE           2 0.15
TOTAL FE           3 0.15
TOTAL FE           4 0.15
TOTAL FE           5 0.15
TOTAL FE           6 0.15
TOTAL FE           7 0.15
TOTAL FE           8 0.15
TOTAL FE           9 0.15
TOTAL FE          10 0.15
MANGANESE             1.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
MANGANESE          1 0.03
MANGANESE          2 0.03
MANGANESE          3 0.03
MANGANESE          4 0.03
MANGANESE          5 0.03
MANGANESE          6 0.03
MANGANESE          7 0.03
MANGANESE          8 0.03
MANGANESE          9 0.03
MANGANESE         10 0.03
ALUMINUM              1.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
ALUMINUM           1 1.00
ALUMINUM           2 1.00
ALUMINUM                 3 1.00
ALUMINUM                 4 1.00
ALUMINUM                 5 1.00
ALUMINUM                 6 1.00
ALUMINUM                 7 1.00
ALUMINUM                 8 1.00
ALUMINUM                 9 1.00
ALUMINUM                10 1.00
TDS                        1.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0
TDS                     1100.0
TDS                     2100.0
TDS                     3100.0
TDS                     4100.0
TDS                     5100.0
TDS                     6100.0
TDS                     7100.0
TDS                     8100.0
TDS                     9100.0
TDS                    10100.0
TSS                        1.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0
TSS                      1 7.00
TSS                      2 7.00
TSS                      3 7.00
TSS                      4 7.00
TSS                      5 7.00
TSS                      6 7.00
TSS                      7 7.00
TSS                      8 7.00
TSS                      9 7.00
TSS                     10 7.00
TEMPERATURE
TEMPERATURE              1  20.
TEMPERATURE              2  20.
TEMPERATURE              3  20.
TEMPERATURE              4  20.
TEMPERATURE              5  20.
TEMPERATURE              6  20.
TEMPERATURE              7  20.
TEMPERATURE              8  20.
TEMPERATURE              9  20.
TEMPERATURE             10  20.
LAST CONSTITUENT
/*
/&
// FIN
```

MODEL RUN 2 - CALIBRATION RUN - STORM SEPT. 17, 1976

WARREN GENERATING STATION, WARREN, PA.

```
* * * *
// JOB SSWMM
// DVC RES
// LBL $LOK01TRCLIB
// LFD TRCLIB
// DVC 20
// LFD PRNTR
// DVC 20    // LFD FORT03
// DVC 51    // VOL TRC001
// LBL 'WARREN STORM 2 SSWMM CALIBRATION 2'    // LFD FORT21
// EXEC SWIM,TRCLIB
/*
21
WARREN GENERATING STATION, WARREN, PA., STORM 2 - SEPTEMBER 17, 1976
 1400745 900.  25. 3 3 7
 3 5 8
 3 5 8
   40     8     1
  0.0  .04  .04  .04  .04  .04  .04  .05  .05  .05
  .05  .05  .05  .11  .11  .07  .07  .07  .07  .03
  .03  .03  .03  .03  .03  .03  .03  .03  .03  .03
  .03  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
    1     1     0                        1
                338. 2.61 100. .018
    2     2     1     1
                          1.0  155.13     .137
    3     2     1     2

    4     1     0                        1
               498.0 1.71 100. .137
    5     2     1     4

    6     1     0                        1
               275.0 2.53 100. .045
    7     2     1     6
                          25.     325.     .022
    8     2     1     7

    .015   0.013          0.001                0.0      0.0      0.0      4.6
          1
       0.0      7     0       21.74
       0.0          0.0         0.0         0.0         0.0         0.0
     0.003       0.003        0.013
                 993.5         1.0         18.7          .3         3.4         6.5
                 993.5         1.0         16.7          .3         3.4         6.5
                 993.5         1.0         16.7          .3         3.4         6.5




       0.0         0.0         0.0         0.0         0.0          .0
       0.0         0.0         0.0         0.0         0.0          .0
                          0.0         0.0        100.0
          1.
     1.3555.
```

```
                     0.0       0.0     100.0
                  1.
              74385.
                     0.0       0.0     100.0
                           1.
                      110955.
 C
/*
/&
// FIN
```

```
* * * *
// JOB LNKPRG
// DVC RES   // LBL $LOK11TRCLIB   // LFD TRCLIB
// DVC 20   // LFD PRNTR
// DVC 20   // LFD FORTC3
// DVC 51   // VOL TRC001
// LBL 'WARREN STORM 2 SSWMM CALIBRATION 2'   // LFC FORT21
// DVC 51   // VOL TRC001
// LBL 'WARREN STORM 2 LNKPRG'   // LFD FORT22
// EXEC LNKPRG,TRCLIB
/$
   21   22
  0.0  30.    1
    6    6    6
    2    3    4    5    6    7
   11    1    2    3    7   10
    2    3    4    5    6    7
   11    1    2    3    7   10
    2    3    4    5    6    7
   11    1    2    3    7   10
 SO4  TOT FE  MN                    AL                TDS   TSS
    5   72
    468.661110232.
  13945.   2060.                        61660.               7222882. 797126.
    5 -3.6  58211.
    664.    108.                         3600.                378712.  41795.
    6  3.6  58211.
    664.    108.                         3600.                378712.  41795.
    7-17.9 289443.
   3400.    537.                        17900.               1883041. 207815.
    8 17.9 289443.
   3400.    537.                        17900.               1883041. 207815.
/*
/&
// FIN
```

```
* * * *
// JOB QUAN
// DVC RES    // LBL .LOR01TRCLIB    // LFD TRCLIB
// DVC 20    // LFD PRNTR
// DVC 20    // LFD FORT03
// DVC 51    // VOL TRC001
// LBL 'WARREN STORM 2 LNKPRG'    // LFD FORT21
// DVC 51    // VOL TRC001
// LBL 'WARREN STORM 2 SETUP'    // LFD FORT23
// DVC 51    // VOL TRC001
// LBL SLSCRAT2    // LFD FORT24
// DVC 51    // VOL TRC001
// LBL 'WARREN STORM 2 QUAN'    // LFD FORT25
// DVC 51    // VOL TRC001
// LBL SLSCRAT4    // LFD FORT26
// DVC 51    // VOL TRC001
// LBL SLSCRAT7    // LFD FORT27
// DVC 51    // VOL TRC001
// LBL SLSCRAT8    // LFD FORT28
// EXEC QUAN,TRCLIB
/*
 0
DATA SET STORM 2, SEPTEMBER 17, 1976  WARREN GENERATING STATION
STORM CONTAINS 40 RAINFALL STEPS
    4         0.0   42
    1    4
    4    1    2    5
    5    3    6    7
    9    8
QUANTITYQUALITY
DATA SET STORM 2, SEPTEMBER 17,1976  WARREN GENERATING STATION
ALL LOADINGS TREATED AS FINITE SOURCES
BASIN CONTAINS 3 SUBCATCHMENTS,2 PIPES,AND 3 INLETS
TOTAL AREA = 6.05 ACRES
    0    1    0
    3  24.   .1  30.  0.0   10     8       0.0  0.0  0.0    1    0    0
         1         2          3          4          5          6          7          8
         9        10
      1  2       2  3      3  4      4  5      5  6      6  7      7  8      8  9
    9   10     265.01      0.0       1.5
    1 5.13   134072.                -1.89      .033
    2 2.69   111546.                -1.59      .033
    3 2.69    29350.                -1.54      .033
    4 2.69    23184.                -1.17      .033
    5 2.69    39078.                -1.17      .033
    6 2.69    66644.                -1.17      .033
    7 2.69    75748.                -1.17      .033
    8 2.59    90203.                 -.80      .033
    9 1.47    47265.                           .033
   10 0.25    47265.                 +.79      .033
99999
    1     1     2              1334.       133.      -1.74      .033      .33
    2     2     3               370.       106.      -1.56      .033      .33
    3     3     4               161.       121.      -1.36      .033      .33
    4     4     5               161.       167.      -1.17      .033      .33
    5     5     6               307.       167.      -1.17      .033      .33
    6    6    7                        460.      167.     -1.17      .033      .33
    7    7    8                        383.      172.      -.98      .033      .33
    8    6    9                        690.      137.      -.40      .033      .33
99999
ENDQUANT
/*
/&
// FIN
```

```
* * * *
// JOB UTLNPS
// DVC RES    // LBL SLOR01TRCLIB    // LFD TRCLIB
// DVC 20    // LFD PRNTR
// DVC 20    // LFD FORT03
// DVC 51    // VOL TRC001
// LBL 'WARREN STORM 2 SETUP'    // LFD FORT23
// DVC 51    // VOL TRC001
// LBL 'WARREN STORM 2 QUAN'    // LFD FORT25
// DVC 51    // VOL TRC001
// LBL SLSCRAT4    // LFD FORT26
// DVC 51    // VOL TRC001
// LBL SLSCRAT7    // LFD FORT27
// DVC 51    // VOL TRC001
// LBL SLSCRAT8    // LFD FORT28
// EXEC UTLNPS,TRCLIB
/$
        QUALITY
         0             0                        0
   0     1    20   36   3    1
SULFATES             1.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
SULFATES           112.00
SULFATES           212.00
SULFATES           312.00
SULFATES           412.00
SULFATES           512.00
SULFATES           612.00
SULFATES           712.00
SULFATES           812.00
SULFATES           912.00
SULFATES          1012.00
TOTAL FE             1.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
TOTAL FE           1 0.15
TOTAL FE           2 0.15
TOTAL FE           3 0.15
TOTAL FE           4 0.15
TOTAL FE           5 0.15
TOTAL FE           6 0.15
TOTAL FE           7 0.15
TOTAL FE           8 0.15
TOTAL FE           9 0.15
TOTAL FE          10 0.15
MANGANESE            1.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
MANGANESE          1 0.03
MANGANESE          2 0.03
MANGANESE          3 0.03
MANGANESE          4 0.03
MANGANESE          5 0.03
MANGANESE          6 0.03
MANGANESE          7 0.03
MANGANESE          8 0.03
MANGANESE          9 0.03
MANGANESE         10 0.03
ALUMINUM             1.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
ALUMINUM           1 1.00
ALUMINUM           2 1.00
ALUMINUM             3 1.00
ALUMINUM             4 1.00
ALUMINUM             5 1.00
ALUMINUM             6 1.00
ALUMINUM             7 1.00
ALUMINUM             8 1.00
ALUMINUM             9 1.00
ALUMINUM            10 1.00
TDS                    1.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0
TDS                 1100.0
TDS                 2100.0
TDS                 3100.0
TDS                 4100.0
TDS                 5100.0
TDS                 6100.0
TDS                 7100.0
TDS                 8100.0
TDS                 9100.0
TDS                10100.0
TSS                    1.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0
TSS                  1 7.00
TSS                  2 7.00
TSS                  3 7.00
TSS                  4 7.00
TSS                  5 7.00
TSS                  6 7.00
TSS                  7 7.00
TSS                  8 7.00
TSS                  9 7.00
TSS                 10 7.00
TEMPERATURE
TEMPERATURE          1   20.
TEMPERATURE          2   20.
TEMPERATURE          3   20.
TEMPERATURE          4   20.
TEMPERATURE          5   20.
TEMPERATURE          6   20.
TEMPERATURE          7   20.
TEMPERATURE          8   20.
TEMPERATURE          9   20.
TEMPERATURE         10   20.
LAST CONSTITUENT
/*
/&
// FIN
```

MODEL RUN 3 - VERIFICATION RUN - STORM AUGUST 26, 1976

WARREN GENERATING STATION, WARREN, PA

```
* * * *
// JOB SSWMM
// DVC 20S
// LBL SLOW.UITRCLIB
// LFL TRCLIB
// DVC 20
// LFD PRNTR
// DVC 23    // LFD FORT03
// DVC 51    // VOL TRC001
// LBL *WARREN STORM 1 SSWMM CALIBRATION #5*    // LFD FORT21
// EXEC SWMM,TRCLIB
/*
21
WARREN GENERATING STATION,WARREN,PA.,STORM 1-AUGUST 26,1976
 1701430 300.   25.  3 3 7
  1 5 8
  7 5 .
    20      8      1
    .0    .16    .10    .16    .15     0.      0.      0.      0.      0.
    0.     0.     0.    0.0    0.1    0.0     0.0     0.0     0.0     0.0
     1      1      0                               1
                      334.   2.51  170.  .113
     2      .      1      1
                                 1.0    155.15        .137
     3      2      1      2

     4      1      1                               1
                      438.   1.71  130.  .137
     5      2      1      4

     6      1      1                               1
                      275.0  2.53  100.  .143
     7      2      1      6
                                 25.       325.        .022
     8      2      1      7

    ..15     1..1              0.011                     0.0         0.0         0.0         4.6
        1
      ...         7      1          11..1
      ...              ...         1.1            .              0.7           0..
     ..12           [illegible]   [illegible]
                    627.5           1.0          1..7              .3          3.4          6.5
                    [illegible]     1.0          18.7              .3          3.4          6.5
                    [illegible]     1.0          1..7              .3          3.4          6.5




       .             ..            ..0            0.0             0.0           .0
       ..            0.            0.0            0.0             0.0           .0
                             .1            1.1            0.0.0
        .
 1.     .
                             1.7           1..            1.0.0
                  1.
```

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```
                  74385.
                         0.0        0.0      100.0
                                  1.
                         110055.
 0
/*
/&
// FIN
```

```
// JOB LNKPRG
// DVC RES   // LBL ALOK01TRCLIB   // LFD TRCLIB
// DVC 20    // LFD PRNTR
// DVC 20    // LFD FORT03
// DVC 51    // VOL TRC001
// LBL 'WARREN STORM 1 SSWMM CALIBRATION #5'   // LFD FORT21
// DVC 51    // VOL TRC001
// LBL 'WARREN STORM 1 LNKPRG CALIBRATION 5'   // LFD FORT22
// EXEC LNKPRG,TRCLIB
/$
   21   22
  0.0  30.    1
    5    6    6
    2    3    4    5    6    7
   11    1    2    3    7   10
    2    3    4    5    6    7
   11    1    2    3    7   10
    2    3    4    5    6    7
   11    1    2    3    7   10
 SO4  TOT FE  MN                     AL                TDS   TSS
    5   72
    465.00 856377.
  1 792.   2351.                    66660.              7861570. 530742.
    5 -3.6  44923.
    323.    126.                     3500.               412200.  27928.
    6  3.6  44923.
    323.    123.                     3500.               412200.  27828.
    7-17.9 223342.
   4117.    537.                    17900.              2049550. 138367.
    8 17.9 223342.
   4117.    537.                    17900.              2049550. 138367.
/*
/&
// FIN
```

```
* * * >
// JOB QUAN
// DVC 20S    // LBL [illegible]    // LFD TRCLIB
// DVC 20    // LFD PRNTR
// DVC 20    // LFD FORT03
// DVC 51    // VOL TRC001
// LBL 'WARREN STORM 1 [illegible] CALIBRATION 5'    // LFD FORT21
// DVC 51    // VOL TRC001
// LBL 'WARREN STORM 1 SETUP CALIBRATION 5'    // LFD FORT23
// DVC 51    // VOL TRC001
// LBL SLSCRAT2    // LFD FORT24
// DVC 51    // VOL TRC001
// LBL 'WARREN STORM 1 QUAN CALIBRATION 5'    // LFD FORT25
// DVC 51    // VOL TRC001
// LBL SLSCRAT4    // LFD FORT26
// DVC 51    // VOL TRC001
// LBL SLSCRAT7    // LFD FORT27
// DVC 51    // VOL TRC001
// LBL SLSCRAT3    // LFD FORT28
// EXEC QUAN,TRCLIB
/*
 C
DATA SET STORM 1, AUGUST 2[illegible], 197[illegible]    WARREN GENERATING STATION
STORM CONTAINS 22 RAINFALL STEPS
     4         0.0   22
     1    4
     4    1    2    5
     5    3    5    7
     7    8
QUANTITYQUALITY
DATA SET STORM 1, AUGUST 25, 197[illegible]    WARREN GENERATING STATION
ALL LOADINGS TREATED AS FINITE SOURCES
BASIN CONTAINS 3 SUBCATCHMTS,2 PIPES,AND 2 INLETS
TOTAL AREA = 5.85 ACRES
     0    1    1
     3  [illegible]   .1  [illegible]  0.0   10    9      0.0  0.0  0.0    1    0    0
          1         2          3          4          5          6          7          8
          9        10
      1  2         2  3       3  4       4  5       5  6       6  7       7  8       8  9
     5   10      2[illegible].01      [illegible]         1.[illegible]
     1  [illegible].13   144372.                -1.39      .033
     2  [illegible].39   111346.                -1.59      .033
     3  2.39    [illegible].                -1.54      .033
     4  [illegible]    [illegible].                -1.17      .033
     5  2.59    39175.                -1.17      .033
     6  [illegible]    [illegible].                -1.17      .033
     7  2.59    [illegible].                -1.17      .033
        [illegible]    [illegible].                 -.[illegible]      .033
        [illegible]    47765.                           .033
        [illegible]    17265.                 -.77      .033
 [illegible]
     1   1                        [illegible].      13[illegible].       -1.74      .033       .33
     2   [illegible]   [illegible]                     3[illegible].      1[illegible].       -1.56      .133       .33
     3   [illegible]   [illegible]                     151.      121.       -1.35      .033       .33
     4   [illegible]   [illegible]                     151.      [illegible]57.       -1.17      .033       .33
     5   [illegible]   [illegible]                     337.      167.       -1.17      .033       .33
```

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```
    6    6    7
    7    7    8                  450.      187.     -1.17      .033      .33
    8    8    9                  343.      172.      -.98      .033      .33
99999                            670.      137.      -.40      .033      .33
ENDQUANT
/*
/&
// FIN
```

```
* * * *
// JOB UTLNPS
// DVC RES    // LBL SLOK11TRCLIB    // LFD TRCLIB
// DVC 20    // LFD PRNTR
// DVC 20    // LFD FORT13
// DVC 51    // VOL TRC001
// LBL 'WARREN STORM 1 SETUP CALIBRATION 5'    // LFD FORT23
// DVC 51    // VOL TRC001
// LBL 'WARREN STORM 1 QUAN CALIBRATION 5'    // LFD FORT25
// DVC 51    // VOL TRC001
// LBL SLSCRAT9    // LFD FORT25
// DVC 51    // VOL TRC001
// LBL SLSCRAT7    // LFD FORT27
// DVC 51    // VOL TRC001
// LBL SLSCRAT8    // LFD FORT28
// EXEC UTLNPS,TRCLIB
/*
        QUALITY
         0                    1                                  0
    0    1    21    36    1     1
SULFATES                      1.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
SULFATES                   112.00
SULFATES                   212.00
SULFATES                   312.00
SULFATES                   412.00
SULFATES                   512.00
SULFATES                   612.00
SULFATES                   712.00
SULFATES                   812.00
SULFATES                   912.00
SULFATES                  1012.00
TOTAL FE                      1.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
TOTAL FE                   1 0.15
TOTAL FE                   2 0.15
TOTAL FE                   3 0.15
TOTAL FE                   4 0.15
TOTAL FE                   5 0.15
TOTAL FE                   6 0.15
TOTAL FE                   7 0.15
TOTAL FE                   8 0.15
TOTAL FE                   9 0.15
TOTAL FE                  10 0.15
MANGANESE                     1.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
MANGANESE                  1 0.03
MANGANESE                  2 0.03
MANGANESE                  3 0.03
[illegible]                4 0.0[illegible]
[illegible]                5 0.0[illegible]
[illegible]                6 0.03
[illegible]                7 0.0[illegible]
[illegible]                8 0.03
[illegible]                9 0.03
[illegible]               1[illegible] [illegible]3
[illegible]                   1.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
[illegible]                [illegible] 1.0[illegible]
[illegible]                [illegible] 1.0[illegible]
```

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```
ALUMINUM                 3 1.00
ALUMINUM                 4 1.00
ALUMINUM                 5 1.00
ALUMINUM                 6 1.00
ALUMINUM                 7 1.00
ALUMINUM                 8 1.00
ALUMINUM                 9 1.00
ALUMINUM                10 1.00
TDS                        1.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
TDS                     1100.0
TDS                     2100.0
TDS                     3100.0
TDS                     4100.0
TDS                     5100.0
TDS                     6100.0
TDS                     7100.0
TDS                     8100.0
TDS                     9100.0
TDS                    10100.0
TSS                        1.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
TSS                      1 7.00
TSS                      2 7.00
TSS                      3 7.00
TSS                      4 7.00
TSS                      5 7.00
TSS                      6 7.00
TSS                      7 7.00
TSS                      8 7.00
TSS                      9 7.00
TSS                     10 7.00
TEMPERATURE
TEMPERATURE              1   20.
TEMPERATURE              2   20.
TEMPERATURE              3   20.
TEMPERATURE              4   20.
TEMPERATURE              5   20.
TEMPERATURE              6   20.
TEMPERATURE              7   20.
TEMPERATURE              8   20.
TEMPERATURE              9   20.
TEMPERATUR              10   20.
LAST CONSTITUENT
/*
//
// FIN
```

MODEL RUN 4 - STORM OCT. 20, 1976

PORTLAND GENERATING STATION, PORTLAND, PA

```
* * * *
// JOB SSWMM
// DVC 20   // LFD PRNTR
// DVC 20   // LFD FORT03
// DVC RES   // LBL $LOAD1TRCLIB   // LFD TRCLIB
// DVC 51   // VOL TRC001
// LBL 'PORTLAND SSW4M'   // LFD FORT21
// EXEC SWIM,TRCLIB
/$
21
PORTLAND GENERATING STATION,PORTLAND,PA.,STORM 1-OCTOBER 20,1976
 1650745 900.  25. 2 2 7
 211
 211
   65   11    1
 0.09 0.10 0.10 0.10 0.10 0.05 0.05 0.05 0.05 0.09
 0.09 0.09 0.09 0.16 0.16 0.12 0.12 0.12 0.12 0.12
 0.12 0.12 0.12 0.12 0.12 0.12 0.12 0.12 0.12 0.12
 0.12 0.12 0.12 0.12 0.12 0.12 0.12 0.12 0.12 0.12
 0.12 0.12 0.12 0.12 0.12 0.12 0.12 0.12 0.12 0.12
 0.12 0.12 0.12 0.12 0.12 0.00 0.00 0.00 0.00 0.00
 0.00 0.00 0.00 0.00 0.00
    1     1     0                          1
                   808.13.55  50.  .05
    2     2     1     1

    3     1     0                          1
                  1220.17.4333.33 .008
    4     2     1     3
                         1.75     817.     .010
    5     1     0                          1
                   698.11.91 100. .0027
    6     2     1     5
                         1.75     462.    .0169
    7     2     2     4     6
                          3.0     223.    .0096
    8     1     0
                  1320.13.23 100.   .15
    9     2     1     8
                         1.75     442.     .010
   10     2     2     7     9
                          3.0     452.    .0096
   11     2     1    10

   .015     .017     .250     .001     .184     3.00     0.52 0.00115      4.6
         1
      0.      7     1          4.00
      0.0        0.0          0.0          0.0          0.0          0.0
   .0055      .0002       .0007       .0003
          998.49      1.18        .014        .0013       .0066        1.61
          997.91      1.11        .016        .003        .015         2.09
          997.91      1.11        .016        .003        .015         2.09
          997.91      1.11        .016        .003        .015         2.09
```

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```
             0.0       0.0       0.0       0.0       0.0       0.0
             0.0       0.0       0.0       0.0       0.0       0.0
                            0.0       0.0     100.0
              1.
         581962.
                            0.0       0.0     100.0
                        1.
                   761429.
                            0.0       0.0     100.0
                                  1.
                             518364.
                            0.0       0.0     100.0
                                            1.
                                       445619.
       0
       /*
       /&
       // FIN
```

```
// JOB LNKPRG
// DVC RES   // LBL .LOK0ITRCLIB   // LFD TRCLIB
// DVC 20   // LFD PRNTR
// DVC 20   // LFD FORT03
// DVC 51   // VOL TRC001
// LBL 'PORTLAND SSWMM'   // LFD FORT21
// DVC 51   // VOL TRC001
// EXT SQ,C,1,CYL,1
// LBL 'PORTLAND LNKPRG'   // LFD FORT22
// EXEC LNKPRG,TRCLIB
/*
   21   22
  0.0  30.     1
    6    6
    2    3    4    5    6    7
   11    1    2    3    7   10
    2    3    4    5    6    7
   11    1    2    3    7   10
 SO4  TOT FE  MN                     AL                 TDS   TSS
    3   72
    3297.24344430.
 169495.  14868.                         297360.                200569324754787.
    4-6.1F   90290.
   3523.     309.                          6180.                 416840.  98818.
    5 6.1F   90290.
   3523.     309.                          6180.                 416840.  98818.
/*
/&
// FIN
// JOB QUAN
// DVC RES   // LBL BLOWDTRCLIB   // LFD TRCLIB
// DVC 20   // LFD PRNTR
// DVC 20   // LFD FORT03
// DVC 51   // VOL TRC001
// LBL 'PORTLAND LNKPRG'   // LFD FORT21
// DVC 51   // VOL TRC001
// EXT SQ,C,1,CYL,1
// LBL 'PORTLAND SETUP'   // LFD FORT23
// DVC 51   // VOL TRC001
// LBL SLSCRAT2   // LFD FORT24
// DVC 51   // VOL TRC001
// EXT SQ,C,1,CYL,1
// LBL 'PORTLAND QUAN'   // LFD FORT25
// DVC 51   // VOL TRC001
// LBL SLSCRAT4   // LFD FORT26
// DVC 51   // VOL TRC001
// LBL SLSCRAT7   // LFD FORT27
// DVC 51   // VOL TRC001
// LBL SLSCRAT8   // LFD FORT28
// EXEC QUAN,TRCLIB
/*
 0
DATA SET STORM 1,OCTOBER 20,1976,PORTLAND GENERATING STATION
STORM CONTAINS 65 RAINFALL STEPS
    3        0.0   67
    1    3
    3    1    4
    4    2    5
QUANTITYQUALITY
DATA SET STORM 1,OCTOBER 20,1976,PORTLAND GENERATING STATION
ALL LOADINGS TREATED AS FINITE SOURCES
BASIN CONTAINS 4 SUBCATCHMENTS,3 PIPES,AND 2 INLETS
TOTAL AREA = 52.97 ACRES
    0    1    0
    3  24.    .1  30.  0.0     7     5        0.0  0.0  0.0     1     0     0
         1           2           3           4           5           6           7
      1  2        2  3       3  4        4  5       5  6
    6    7     337.32        0.0         1.5
    1 8.35     93861.                   -3.31       .033
    2 8.05     92022.                   -2.37       .033
    3 8.05     74722.                   -3.04       .033
    4 8.05    130490.                   -3.71       .033
    5 6.44    172638.                   -3.26       .033
    6 5.75     71779.                     0.0       .033
    7 4.59     71779.                    -.48       .033
99999
    1    1    2                 402.44    233.23     -2.84      .033        .2
    2    2    3                 402.44    224.09     -2.71      .033        .2
    3    3    4                 241.46    245.43     -3.38      .033        .2
    4    4    5                 965.85    208.85     -7.49      .033        .2
    5    5    6                 804.68    178.36     -1.63      .033        .2
99999
ENDQUANT
/*
/&
// EOJ
```

```
* * * *
// JOB UTLNPS
// DVC RES   // LBL $LOK01TRCLIB   // LFD TRCLIB
// DVC 20   // LFD PRNTR
// DVC 20   // LFD FORT03
// DVC 51   // VOL TRC001
// LBL 'PORTLAND SETUP'   // LFD FORT23
// DVC 51   // VOL TRC001
// LBL 'PORTLAND QUAN'   // LFD FORT25
// DVC 51   // VOL TRC001
// LBL SLSCRAT4   // LFD FORT26
// DVC 51   // VOL TRC001
// LBL SLSCRAT7   // LFD FORT27
// DVC 51   // VOL TRC001
// LBL SLSCRAT8   // LFD FORT28
// EXEC UTLNPS,TRCLIB
/$
        QUALITY
         0              0                        0
    0    1   20   36    3    1
SULFATES              1.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
SULFATES           114.00
SULFATES           214.00
SULFATES           314.00
SULFATES           414.00
SULFATES           514.00
SULFATES           614.00
SULFATES           714.00
TOTAL FE              1.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
TOTAL FE            1 .50
TOTAL FE            2 .50
TOTAL FE            3 .50
TOTAL FE            4 .50
TOTAL FE            5 .50
TOTAL FE            6 .50
TOTAL FE            7 .50
MANGANESE             1.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
MANGANESE           1 .05
MANGANESE           2 .05
MANGANESE           3 .05
MANGANESE           4 .05
MANGANESE           5 .05
MANGANESE           6 .05
MANGANESE           7 .05
ALUMINUM              1.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
ALUMINUM            1 0.5
ALUMINUM            2 0.5
ALUMINUM            3 0.5
ALUMINUM            4 0.5
ALUMINUM            5 0.5
ALUMINUM            6 0.5
ALUMINUM            7 0.5
TDS                   1.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
TDS                 1 65.
TDS                 2 65.
TDS                 3 65.
TDS                      4   65.
TDS                      5   65.
TDS                      6   65.
TDS                      7   65.
TSS                          1.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0
TSS                      1   15.
TSS                      2   15.
TSS                      3   15.
TSS                      4   15.
TSS                      5   15.
TSS                      6   15.
TSS                      7   15.
TEMPERATURE
TEMPERATURE              1   20.
TEMPERATURE              2   20.
TEMPERATURE              3   20.
TEMPERATURE              4   20.
TEMPERATURE              5   20.
TEMPERATURE              6   20.
 EMPERATURE              7   20.
 AST CONSTITUENT

   FIN
```

TECHNICAL REPORT DATA

(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA-600/2-77-199

2.

3. RECIPIENT'S ACCESSION NO.

4. TITLE AND SUBTITLE Sampling and Modeling of Non-Point Sources at a Coal-Fired Utility

5. REPORT DATE September 1977

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9. PERFORMING ORGANIZATION NAME AND ADDRESS
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15. SUPPLEMENTARY NOTES IERL-RTP project officer for this report is D. Bruce Harris, Mail Drop 62, 919/541-2557.

16. ABSTRACT The report gives results of a measurement and modeling program for nonpoint sources (NPS) from two coal-fired utility plants, and the impact of NPS on receiving waters. The field measurement survey, performed at two utility plants in Pennsylvania, included measurement of overland runoff from NPS and river sampling upstream and downstream of each plant site. NPS sampled were storm water runoff and leachate from coal storage piles and runoff from impervious areas such as parking lots and roofs which were covered with dust fallout from coal and ash handling operations. A mathematical model was developed to simulate both the quantity and quality of industrial NPS pollution and its impact on receiving waters. Field data indicated that NPS pollution from utilities had little impact on the two rivers, compared to the impact from sources upstream of each site. Modeled results compared to field measurements within a factor of 4 for both the quantity and quality of storm water runoff and its impact on the quality of the receiving waters. Field survey results indicate that, for a cost-effective program, sampling must be supplemented with modeling (the modeling results indicate that the developed model can be used with a minimum of field data to successfully simulate industrial NPS pollution and its impact on receiving waters for the utility industry).

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS		b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group	
Pollution	Mathematical Models	Pollution Control	13B	12A
Utilities	Runoff	Stationary Sources		08H
Combustion	Stream Pollution	Non-Point Sources	21B	
Coal	Coal Storage		21D	08I
Coal Handling	Leaching		15E	07D,07A
Measurement	Dust		14B	11G

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